Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

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OCTOBER 1959

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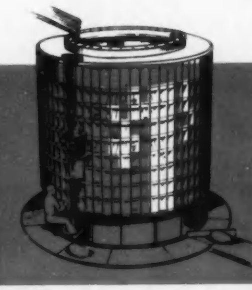
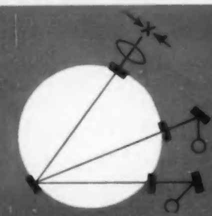
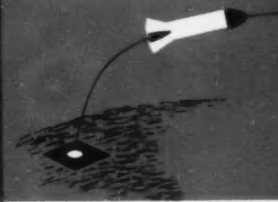


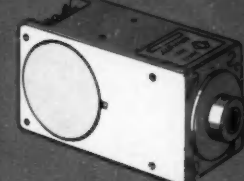
Emission Spectroscopy Speeds Metals Analysis



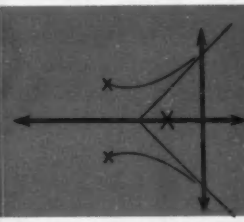
Gyros Zero Thor on Target



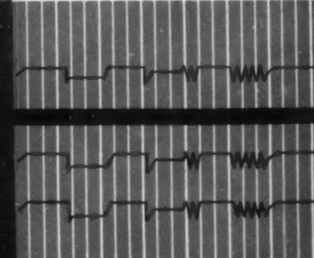
German Stepping Motor Has Three Solenoids



Using the Root Locus



Checking Taped Numerical Control Programs



1200 Temperatures entrusted to two L&N data systems!

At the new Bergen Generating Station of Public Service Electric and Gas Company, two 600 point L&N Data Systems will monitor bearing, boiler tube, and condensate temperatures for No. 1 and 2 Units.

Electric typewriters will log data for each unit on continuous 8½" wide log sheets, perforated every 11" . . . one typewriter logging all 600 temperatures while the other is recording off-normals (in red) and up to 10 trends. All inputs are scanned every two minutes for off-normals, with scanning proceeding during logging and trending. As an example of the system's safety measures, all data can go through either typewriter so the operator is never left without vital information.

In designing this system, Public Service and L&N engineers made a thorough study of Bergen's requirements. L&N's contribution was based on 30 years' experience in power plant measurements and an expert knowledge of data processing. For data systems and other power plant controls, call your nearby Field Office or Leeds & Northrup Co., 4918 Stenton Ave., Philadelphia 44, Pa.

Data Systems engineered to power-plant standards by **LEEDS & NORTHRUP**

Instruments · Automatic Controls • Furnaces

CIRCLE 1 ON READER SERVICE CARD

Control ENGINEERING

OCTOBER 1959

VOL. 10 NO. 10

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

Continued on next page

What's New in the Control Field

PRINT ORDER THIS ISSUE 33,701

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solid state

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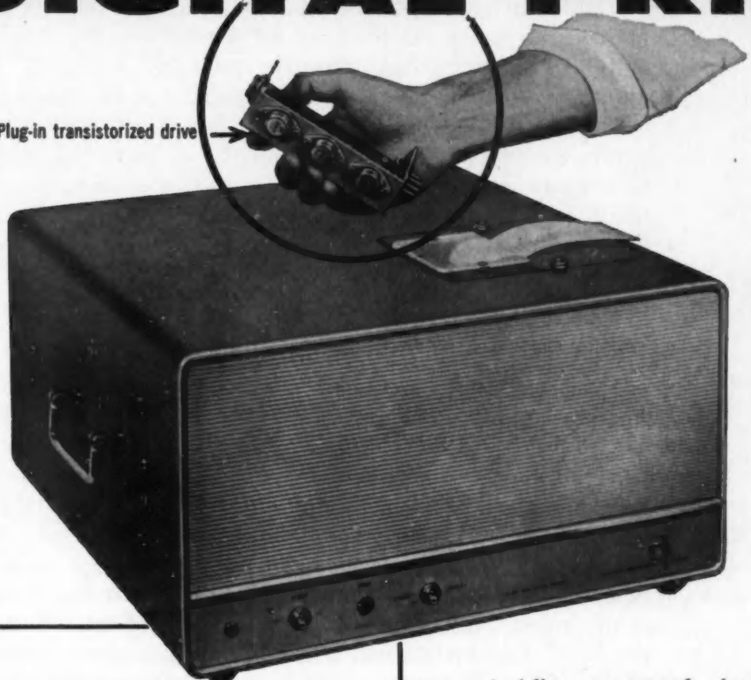

Announcing the 400 CT -

The most versatile digital printer ever made

SPECIFICATIONS

Printout capacity	6 digits standard.
Accuracy	determined by basic counting instrument.
Display time	0.2 seconds minimum, maximum controlled by the counter.
Weight	60 lbs.
Power requirements	115 volts ±10%, 50-60 cps 25 watts
Dimensions	17" W x 8½" H x 16½" D. (Rack mounting available as option D.)
Warranty	One year on electronics; 1.5 million lines @ 4 lines per second on matrix; 10 million lines @ 4 lines per second on printer assembly, or 1 year, whichever occurs first.
Price	$1350.00. Add $10.00 for rack mount.

* 4 lines per second printout * Takes 1-2-2-4 or 1-2-4-8 four line code * No stepping switches * Operates from only 6 volt input * Parallel entry * Special options available including 10 line and analog output * 6 digit printout, up to 12 digits on special order * Rugged unitized construction * Completely compatible with CMC's new solid state frequency-period counters, and other types of transistorized counting equipment.

For a demonstration of this remarkable new printer and complete technical information, call your nearby CMC engineering representative or write to us direct. Please address Dept. 0810.

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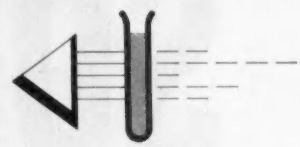
CIRCLE 5 ON READER SERVICE CARD

SHOPTALK

Analysis Instruments—reprints available



The symbol at the right has over the past two years identified CONTROL ENGINEERING's "Analysis Instrumentation Series". Seventeen articles on commercially important analytical methods detail such items as basic analysis procedure, available instruments, and types of streams for which each is suited—112 pages in all.

Eight articles have been available for some time in two packaged reprints. A third reprint, containing the balance of the AIS articles (including the final one appearing this month—"Emission Spectroscopy") will be ready soon. Nowhere, we believe, is there so much factual information on stream analyzers—from the instrument and control engineer's viewpoint—as in these reprints. One oil company is using them as texts for training engineers on quality-measuring instruments. See reprint coupon, p. 211, for details of contents. Parts I and II, 60 cents each; Part III, 90 cents; all three for $1.75.

World News covers all

Sharp-eyed byline readers will notice that two of this month's feature articles were authored by McGraw-Hill World News editors, in addition to their usual number of contributions to our news columns. Writing technical features is just one of the duties of our far-flung representatives. Keeping the pulsebeat of news alive to the home office is, of course, their main responsibility. And to do this, you may be interested to know, McGraw-Hill maintains the world's third largest publisher-owned news gathering agency—after the N. Y. *Times* and *Time-Life*. World News has representatives in 39 states and full-time bureaus in nine cities. Overseas they cover their beats with full-time bureaus in eight countries (including one in Moscow) and stringers in 60 countries. All-in-all, World News has 63 full-time editors and 130 stringers in the field.

Upcoming in November

Here's just a glance at some of what's scheduled for next month: a full-scale report on a new Japanese numerical control system, a follow-up to William Bell's article on proposal evaluation—this time on system bid preparation, a description of a British machine that automatically teaches keypunch operators, and a report on OPCON installation.

Space for sale

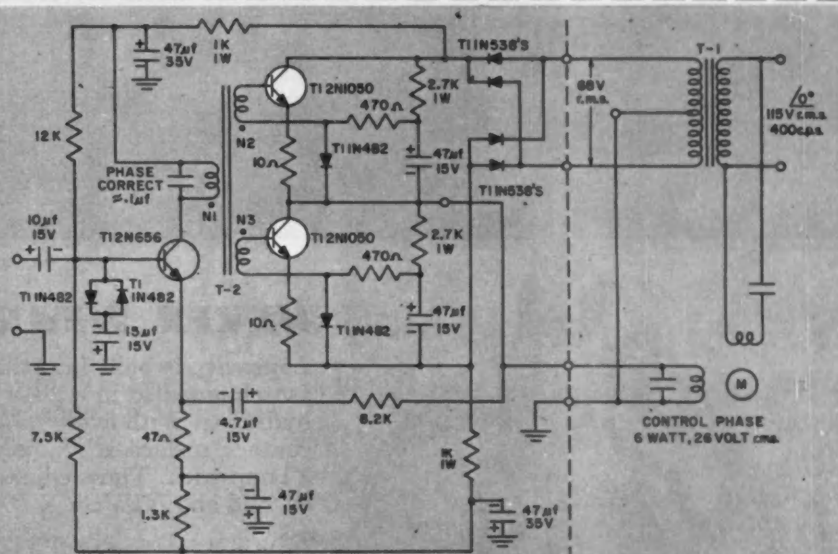
With this issue we welcome our new advertising sales manager, John G. Zisch, who replaces Russ Berg. John comes from Chicago, where he was CtE's district manager; previously he was business manager for the J. B. Rea Co.

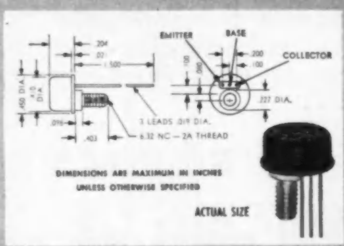
How to get 55% over-all efficiency in transistorized 6-watt servo amplifier

HIGH-EFFICIENCY SERVO CIRCUIT REQUIRES . . .

- **no output transformer**
- **no center-tap motor winding**

Higher over-all efficiency than in a conventional Class-B push-pull amplifier is achieved in this servo by use of unfiltered rectified a-c for current supply voltage—with resulting reduction in size, weight and power supply requirements. This higher efficiency means greater transistor reliability, smaller heat sink and/or higher allowable ambient temperatures. Output will remain sinusoidal when amplifier is overdriven.





TRANSFORMERS

T-1 400 cps, 12-watt power transformer step-down 115 volt to 68 volt c.t.

T-2 400 cps, 65-mw driver transformer. Turns ratio N1: N2: N3 = 2: 1: 1
Primary Current = 10 ma d-c. Primary Inductance = 1.5 hy.

...with TI 2N1050 N-P-N silicon transistors!

Exclusive TI 2N1047 intermediate-power series now gives you maximum design flexibility plus high efficiency . . . all in a miniature package!

Consider the design flexibility made possible by the exclusive features of this series . . . 40 watts dissipation at 25°C case temperature . . . unique stud mounting for maximum thermal efficiency . . . 80- and 120-volt BV_{CEX} . . . 15-ohm R_{CS} . . . −65°C to +200°C operating and storage range . . . choice of beta spreads.

Apply TI's guaranteed specs to your design situations today. This use-proved series is available off-the-shelf — *at factory prices* — in 1-999 quantities from your nearby authorized TI distributor, and in production quantities from your TI sales office.

Write on your company letterhead for illustrated TI APPLICATION NOTES on the transistorized servo amplifier.

PARAMETER	TEST CONDITIONS		2N1047 min.	2N1047 max.	2N1048 min.	2N1048 max.	2N1049 min.	2N1049 max.	2N1050 min.	2N1050 max.	unit
BV_{CEX} Breakdown Voltage	$I_C = 250\ \mu a$	$V_{BE} = -1.5v$	80		120		80		120		v
BV_{EBO} Breakdown Voltage	$I_E = 250\ \mu a$	$I_C = 0$	10		10		10		10		v
I_{CBO} Collector Cutoff Current	$V_{CB} = 30v$	$I_E = 0$		15		15		15		15	µa
h_{FE} Current Transfer Ratio †	$V_{CE} = 10v$	$I_C = 200ma$	12	36	12	36	30	90	30	90	—
h_{IE} Input Impedance †	$V_{CE} = 10v$	$I_B = 8ma$		500		500		500		500	ohm
R_{CS} Saturation Resistance †	$I_C = 200\ ma$	$I_B = 40ma$		15		15		15		15	ohm
V_{BE} Base Voltage †	$V_{CE} = 15v$	$I_C = 500ma$		10		10		10		10	v

†Semiautomatic testing is facilitated by using pulse techniques to measure these parameters. A 300-microsecond pulse (approximately 2% duty cycle) is utilized. Thus, the unit can be tested under maximum current conditions without a significant increase in junction temperature, even though no heat sink is used. The parameter values obtained in this manner are particularly pertinent for switching circuit design and, in general, indicate the true capabilities of the device.

germanium and silicon transistors
silicon diodes and rectifiers
fan-Ti-cap solid tantalum capacitors
precision carbon film resistors
sensistor silicon resistors

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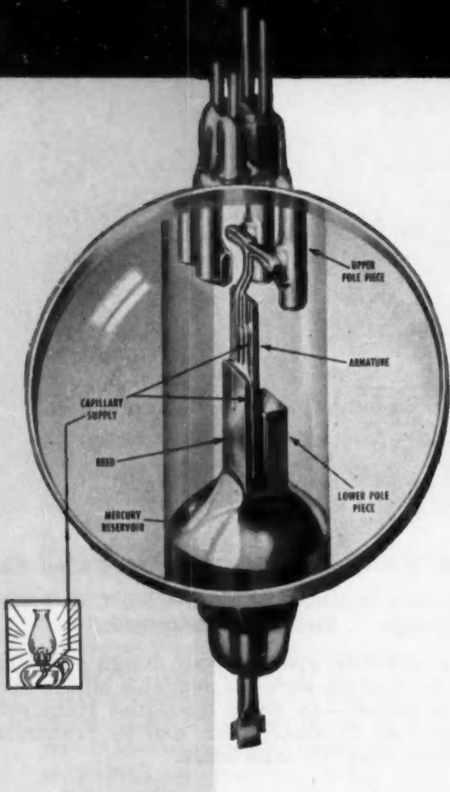
CIRCLE 7 ON READER SERVICE CARD

Over 8 billion* operations

CLARE Mercury-Wetted

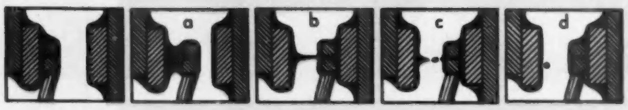
*with contact load of 250 volt-amperes.



NEVER WEAR OUT

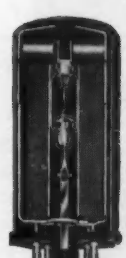
Longevity is built into these relays. The basic magnetic switch is sealed in a glass capsule filled with pressurized hydrogen. With every make and break the mercury-film contact surface is renewed . . . by capillary action, like a lamp wick. These contacts never get dirty, never lock or weld and *NEVER WEAR OUT*.

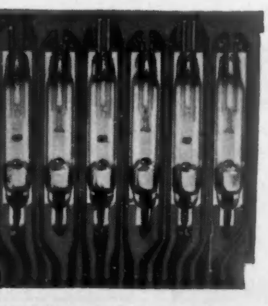
NEVER CHATTER OR BOUNCE



Contact closure between the two liquid surfaces bridges any mechanical chatter and prevents its appearing in the electrical output. (a) Filament of mercury forms between the contacts as they separate. (b) This becomes narrower in cross section and (c) finally parts at two points, allowing a globule of mercury to fall out. (d) The extremely fast break minimizes the arc and adds greatly to contact load capacity.

NO MAINTENANCE REQUIRED





HG Relay cutaway to show magnetic switch surrounded by operating coil and encased in a metal housing.

HGS Relay cutaway to show biasing magnets attached to the ends of the side plates.

HG6F Relay printed circuit panel showing six in-line mercury-wetted contact switches mounted in minimum space.

With all working parts sealed and switches and coils enclosed in metal housings, these relays are tamper-proof and always in constant adjustment. They require no maintenance whatsoever.

–with no maintenance!

Contact Relays on test 4 years

A FULL LINE OF THE MOST RELIABLE, MOST DURABLE RELAYS EVER MADE

single form D

Type HG. Capable of up to 100 operations a second. Load-handling capacity to 5 amperes and up to 500 volts. (250 va max. with proper contact protection.)

single form D

Type HGP. Can be factory adjusted to provide single side-stable, bi-stable or chopper characteristics.

single form D

Type HGS. Biased with permanent magnets. Speed up to 200 cps. Sensitivity as low as ±2.5 milliwatts. Handles up to 2 amperes, up to 500 volts (100 va max. with proper contact protection.)

four form D

Type HG4. Four form D switches enclosed in a single housing with coil. Plug-in assembly (shown) is standard. Other mountings available.

two or three form D

Types HG2 and HG3. Two or three form D Switches enclosed in a single housing. HG2 has 8 or 11-pin octal style plug. An 11-pin base is standard for HG3.

six in-line flat pack

Type HG6F. Six switches mounted in line on printed circuit panel surrounded by single coil. Flat, compact assembly. Over-all dimensions: 3.640" x 3.125" x 1.046". Uses standard 32 or 36 terminal printed circuit socket.

For complete information on CLARE Mercury-Wetted Contact Relays or on the entire CLARE line of superior relays and electronic components address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Limited, P. O. Box 73, 2700 Jane Street, Downsview, Ontario. Cable Address: CLARELAY.

Send for Catalog 201

CLARE RELAYS

FIRST in the Industrial Field

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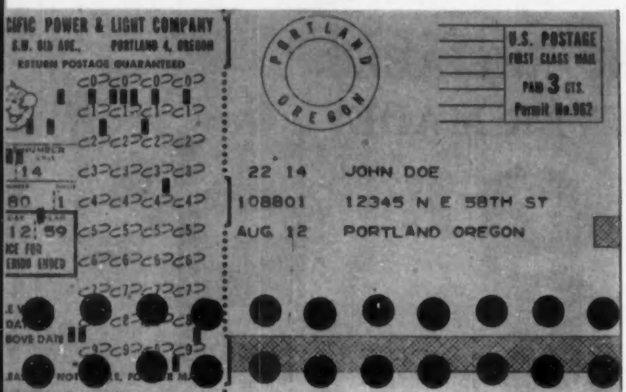
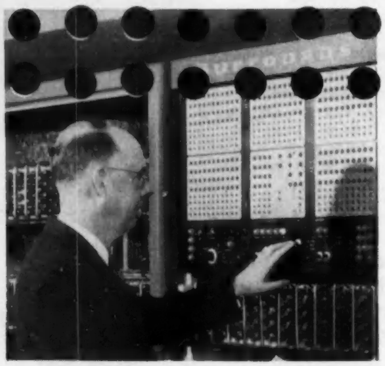
A Statement from Pacific Power & Light:

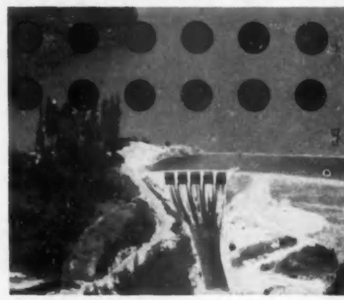
"Our Burroughs 205 computer saves us money in many ways..."



Paul B. McKee, Chairman of the Board and Don C. Frisbee, Treasurer



Programming Head Vern C. Thomas



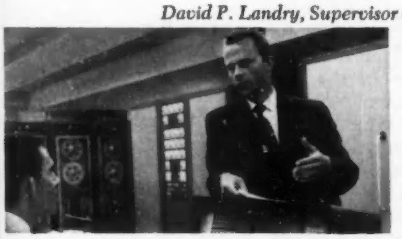
"Our Burroughs 205 computer saves us money in many ways . . . Customer Billing, Accounting, Plant Expansion Studies, and Area and Resource Development."

PAUL B. MC KEE
Chairman of the Board, Pacific Power & Light

In many ways, a Burroughs 205 electronic data processing system is serving over 300,000 customers in the Great Northwest. The system is installed at Pacific Power & Light in Portland, Oregon, and is currently being used for accounting and engineering jobs.

In 1948 the billing at Pacific Power & Light was centralized on key-driven equipment. Three years later, a forward-thinking management initiated studies of the electronic data processing field. Stanford Research Institute was called in to work with key PP&L accounting personnel in doing a study. After an exhaustive report on computer requirements prepared in 1956, management was ready to make a selection. States PP&L's Chairman of the Board Paul B. McKee, *"We were satisfied that we had researched the problem thoroughly and were able to make a completely objective choice. We purchased a Burroughs 205 system simply because it supplied the best answer to our needs."* Delivery of the 205 was in May, 1957. The customary step from key-driven machines to punched card equipment was completely bypassed, and the first electronically processed bills were sent out in July

David P. Landry, Supervisor of Electronic Data Processing



Dr. James Ward, Director of Research

of 1957. Regarding their venture into electronic data processing equipment, PP&L's treasurer Don C. Frisbee says, *"At the time we made the jump into electronic data processing there was no established precedent in the utility field. However, with our problems of mounting paperwork, plus our growing needs for solutions to so many engineering problems, we felt it was necessary to make a pioneering move from key-driven equipment directly to an EPD system."*

The customer accounting task for PP&L's 205 was a stickler because their billing problems are so numerous. PP&L's lines extend through Oregon, Washington, Wyoming, Montana and Idaho, and within this large service territory the company maintains 23 districts and 52 offices. Because its territories are so diverse, there are more than 200 different rate schedules. It also reports to five state commissions.

Despite the many complexities, *in one pass* PP&L's 205 computer now processes 30,000 items in one day. And during this same single pass, it bills customers, updates account records maintained on magnetic tape, processes connect and disconnect orders, local bills, adjustments, cash payments and myriad data changes.

Vice-President and Controller of PP&L, George Mackenzie points out, *"The computer didn't solve our paperwork problems overnight. But then we didn't expect it to. We did expect the 205 to enable us to serve our customers faster and more efficiently. . . and at considerable savings. It has more than met these expectations."* In addition, David P. Landry, Supervisor of Electronic Data Processing at PP&L says, *"Our 205 has not only been fruitful from a tangible dollars and cents point of view, but the computer is also providing new sources of information for management."*

PP&L's 205 has operated on the average of 17 hours per day over the last two years. The company has not been content to restrict its system solely to commercial data processing. PP&L is using its 205 to solve complex engineering problems concerned with the generation, transmission and distribution of power. One of the engineering problems taken over by the machine is scheduling a most efficient use of water stored behind PP&L's three Lewis River Dams to harness the full power potential of the river. The 205 program is, in effect, a mathematical model of the Lewis River hydroelectric facilities. According to Dr. James Ward, Director of Research, *"Its use has saved many hours of tedious calculations. The computer completes in one minute the solution of an operation study which requires 12 to 14 hours when done manually."*

The 205 is also tackling other thorny engineering problems. Routines have been developed for use in planning and designing transmission lines. Another problem involves the calculation of the large short circuit currents which occur when lightning strikes a line. Dr. Ward anticipates that *"the Burroughs 205, in solving technical problems for us, will provide the capabilities of a large scale analog computer, usually used for this work, and costing several hundred thousand dollars."*

In using their 205, PP&L has formed its own operating team. Board Chairman McKee points out, *"Although our data processing equipment team is composed of our own company-experienced personnel, the training they have received from Burroughs has been invaluable in the success of our program. We have found that the backing and service a manufacturer provides is as important as the equipment itself."*

Today, PP&L is working on extending their accounting and engineering uses of the 205 even further. They are confident in their explorations because the 205 has already proven its versatility. And there is assurance too, because all of Burroughs' complete line of advanced data processing systems are designed with customer expansion in mind. These Burroughs computers are currently aiding hundreds of other business and scientific users. For additional information on how the 205 or other Burroughs computing systems can help in your business, write ElectroData Division, Pasadena, California.

Burroughs Corporation *"NEW DIMENSIONS/in electronics and data processing systems"*

FEEDBACK

READER FORUM

This month Readers' Control Workshop gives 'way to a question-and-answer forum on technical details of what has proved to be a very stimulating and useful article, "How to Reduce Interaction Between Control Loops", by Jake E. Valstar of Hughes Aircraft Co., pp. 112-113 of the June '59 issue.

We will pay forum participants whose comments we publish. Send in your problem—for cash and for answers from other subscribers. Ed.

To the Editor—

I have just read "How to Reduce Interaction Between Control Loops" in the June '59 issue of Control Engineering, and I found it interesting and informative. Two questions bother me.

1. Why is the temperature control loop omitted from the discussion? A change in controlled temperature (due to a change in the heating or cooling fluid or other cause) will result in a change in F_1, which in turn causes F_2 to change. It would seem all three loops interact.
2. In the example, the influence of valve B was investigated by increasing C_B, i.e., *increasing* F_2, but the influence of valve A was investigated by *decreasing* C_B, i.e., decreasing F_1. Why not change both in the same direction? This does not alter the conclusions reached, but does alter the magnitude of the cross-gain ratios.

C. A. Prior
Diamond Alkali Co.
Cleveland, Ohio

To the Editor—

With great interest I read the thought-provoking article by Jake Valstar on "How to Reduce Interaction Between Control Loops". After going through his sample problem, it occurred to me that the solution could be simplified if the valves were manipulated independently to produce the same change in total flow, with corresponding pressure changes of different magnitude. The cross-gain ratio then becomes the ratio of the pressure changes:

$$\frac{G_{B_1}G_{A_2}}{G_{B_2}G_{A_1}} = \frac{\Delta(P_2 - P_3)_{const\ A}}{\Delta(P_2 - P_3)_{const\ B}}$$

The problem then reduces to the simple expression:

$$\frac{\Delta(P_2 - P_3)_A}{\Delta(P_2 - P_3)_B} = \frac{P_2 - P_1}{P_2 - P_3}$$

For Mr. Valstar's sample problem, the answer obtained by this means is -1.86, whereas the published answer was -3.1. It will be noted, however, that Mr. Valstar used conductivity values of 37 for C_A and 51 for C_{A+B}; the more exact conductivity values of 37.2 and 50.7 produce the different answer. *Considerable accuracy is required to obtain reliable results from incremental changes.*

It is important to note that the derived expression contains no terms peculiar to the branch line through the heat exchanger, hence the branch line variables do not affect the cross-gain ratio. The stability of the system does, however, change with pressure conditions; therefore, the combination of loops providing the best stability at one setting may not provide the best stability at another.

The complete derivation is enclosed.

Francis G. Shinskey
Olin Mathieson Chemical Co.
Niagara Falls, N. Y.

And the author comments

To the Editor—

Mr. Prior asks in his first question if there are three interacting loops instead of two. Indeed, there are as many interacting loops as there are controllers tied into a system. However, the temperature control system was, relatively speaking, very slow. The two fast liquid-flow loops balanced out so quickly that their influence was not noticeable in the temperature loop. The effect of the slow variations of the temperature-control valve can be considered as an input to the two liquid-flow systems. (Another input is $P_1 - P_3$.)

About Mr. Prior's second question, I can say that the direction of the increments is of no importance. The incremental method was used to cal-

FEEDBACK

culate the process gains. The sign of a process gain is independent of the sign of the increment.

Mr. Shinskey found that we have to be very accurate when using the incremental method. I really enjoyed reading his letter. At the time that I set up the example I sneakily kept $P_1 - P_2$ quite a bit larger than $P_2 - P_3$ to obtain the desired answer. Mr. Shinskey very cleverly discovered my secret.

It is true indeed that we need the other scheme when we pass through the condition at which $P_1 - P_2 = P_2 - P_3$. When we take the right scheme for the normal conditions we will have the best operation most of the time.

Jake E. Valstar
Hughes Aircraft Co.
Newport Beach, Cal.

Tch, Tch, Jake, watch your accuracy; our subscribers have sharp eyes. We will be glad to furnish copies of Mr. Shinskey's complete derivation to those who write us for copies. Ed.

Tell us more.

To the Editor—

Reference is made to the article, "A Remarkable New Switching Form", which appeared in the July '59 issue of Control Engineering.

We are currently engaged in a research program sponsored by the Bureau of Ships, Code 695 B, concerning the radio frequency interference characteristics of various switching devices. This new relay is of interest to us in this program.

Martin M. Abromavage
Jansky & Bailey, Inc.
Washington, D. C.

Because the relay is free of arcing and inductive effects, it should be quite "quiet"; however, its developer has made no RF interference tests yet. Ed.

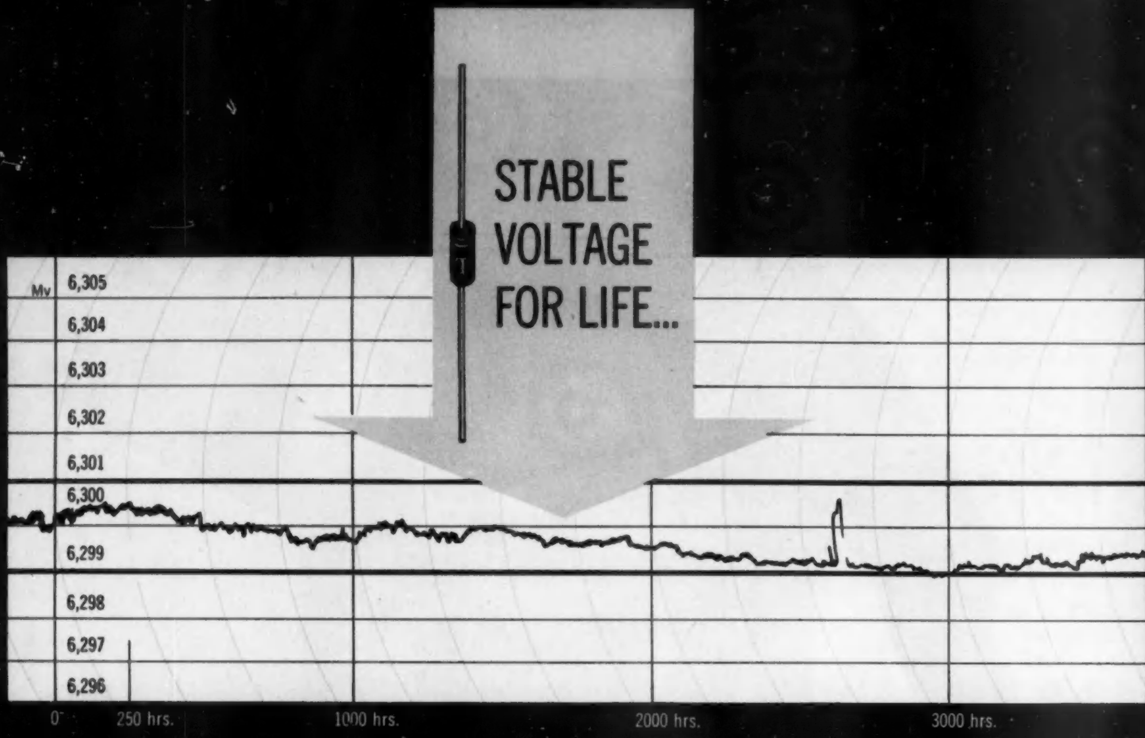
Will it work upside down?

To the Editor—

We are writing in regard to your article on the electrochemical relay appearing in the July issue of Control Engineering. We are most interested in the catalytic wire used, since for our applications the relay must be completely sealed and capable of being inverted.

John Munick
NASA
Langley Field, Va.

The manufacturer claims that the relay will operate reliably in any attitude, but he prefers not to reveal the nature of the catalyst. Ed.



NEW ULTRA-STABLE ZENER DIODES

SPECIFICATIONS					RATINGS	
Type	Voltage Range at I_Z = 7.5 ma at 25°C (Volts)		Temp. Coefficient[2] (−55°C to +100°C) at I_Z = 7.5 ma (%/°C)	Maximum Dynamic[3] Resistance at 25°C at I_Z = 7.5 ma (ohms)	Operating and Storage Temperature Range (°C)	Max. Operating Temp. at I_Z = 7.5 ma (°C)
	Min.	Max.				
1N821	5.9	6.5	±.01	15	−65 to +150	+125
1N822[1]	±5.9	±6.5	±.01	15	−65 to +150	+125
1N823	5.9	6.5	±.005	15	−65 to +150	+125
1N824[1]	±5.9	±6.5	±.005	15	−65 to +150	+125
1N825	5.9	6.5	±.002	15	−65 to +150	+125
1N827	5.9	6.5	±.001	15	−65 to +150	+125

[1]Double anode types.
[2]Determined by measuring a change of voltage from −55°C to +25°C and a change of voltage from +25°C to 100°C.
[3]The Dynamic Resistance is measured by superimposing a small A.C. Signal upon the test D.C. Current. (I_{AC} RMS ≤ 1/10 I_{DC} Test)

1N822 and 1N824 types meet all specifications, including temperature coefficient, in both directions.

This new line of subminiature silicon voltage references features a combined lower dynamic resistance and voltage stability exceeding that of *any* standard cell.

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CIRCLE 16 ON READER SERVICE CARD

Harry Ankeney

faces a challenge in Cincinnati

Although he arrived on the Milwaukee scene a century or so later than the first beer brewers, Harry Ankeney has done his share in making the area famous. The Giddings & Lewis Machine Tool Co. brought Harry to neighboring Fond du Lac at the beginning of 1952—just after the firm had taken a forward look and decided to gamble R&D money on the then unproven concept of numerical control. Ankeney's job as project engineer was to write the initial specifications for the General Electric (control) and MIT (director) portions of the first tape-operated skin mill. Demonstrations of the revolutionary G&L machine impressed officials of the Air Material Command, who were just about to issue purchase orders for a large number of tracer-controlled skin mills intended for use by aircraft contractors. The impression was so profound that the AMC skin-mill specifications were changed to reflect it, the words "numerical control" being substituted for the original "tracer control". Later, AMC went on to purchase almost 100 of the big skin mills and the numerical control field was on its way.

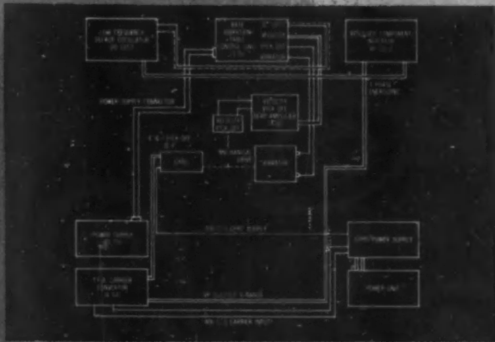
The gamble paid off for Ankeney, who advanced to the post of manager of research, and for G&L, which won contracts for about half of the AMC machines. To help fulfill its share of the program, G&L set up Concord Controls, Inc., in Boston, as manufacturers of the computing director (needed for the preparation of magnetic control tapes). Today, tape-controlled G&L mills are routinely cutting metal in aircraft plants throughout the country.

A logical question at this point for a control engineer who has successfully wrapped up a long and complex development program in a frontier technology is, "What's next?" Ankeney's answer is simply, "More numerical controls". And to make sure that Harry backs up this answer, G&L has transferred him to Cincinnati for a long-term stay. Here Ankeney faces the challenge of a massive engineering project: the application of numerical controls to the products of the Cincinnati-Bickford Div. The broad responsibilities given him are strong testimony to G&L's faith in both Harry and numerical controls. His duties: (1) assume the position of manager of Cincinnati-Bickford and (2) organize and manage an electrical control design and manufacturing facility in Cincinnati.

The first product of the new Cincinnati-Bickford endeavors has just been announced. This is a large (38 x 50 in.) numerically-controlled positioning table for drill presses, featuring a two-electric-motor-per-axis drive that delivers the amazingly high slew speed of 360 in. per min. To come in the near future is the forerunner of a new family of numerically-controlled tool-changing machines.

The path Ankeney followed to numerical control began in 1935 with an electrical engineering degree from Iowa State College. He plunged immediately into control engineering work with Cutler-Hammer, where he stayed for over 10 years. The next seven years were spent at the Verson All-Steel Press Co. as chief electrical engineer and works manager and as a key figure in Verson's heavy press program. In all of these moves—including the latest to Cincinnati—Harry was followed dutifully by his fine family, which includes wife Polly, daughters Marilyn and Barbara, and sons John and Daniel.

Ankeney believes that the rapidly increasing "control content" of industrial machines will enhance opportunities of control engineers to play a more important role in management. As he phrases it, "The chief engineer should be thinking not only about what his company is making, but also about what the company should build in the future." Among the sources Ankeney taps for products to come are customers and field salesmen. As any plant manager knows, the latter are forever pressing the home office for modifications and new products that are outside the company's standard line. Usually such requests fall upon deaf ears. But Ankeney thinks that this situation may change in the future, "because with the right controls available, the 'odd-ball' machine should be a lot easier to make."



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GYRO TEST CONSOLE

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Angular Velocity range: 0-60° peak
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PROCESS RESPONSE ANALYZER JY 743 SPECIFICATIONS

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Square wave output: 0-20 volts peak
Display: 2 meters 5½"
Sensitivity: 3 mV peak maximum to 3300 mV
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Input impedance: 1M ohm

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A shrieking horn means trouble! Before gases can accumulate in the mine—jeopardizing the lives of hundreds—repair crews get the signal and start working on the failing fan.

Cable for a control system such as this must be the ultimate in reliability. "We've had experience with Rome's borehole cable and other types of Rome cable," says the chief outside electrician, "so I recommended Rome's control cable for this important job."

It went up very quickly—a crew of seven strung the first 16,000 feet over rugged, wooded and hilly terrain in only 14 days. That's *half* the time such an installation normally takes. The reason? Rome supplied a factory-assembled self-supporting-type cable to save the time and expense of on-the-job assembly.

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Rome Cable manufactures various types of thermosetting and thermoplastic control cables to meet specific electrical, environmental, installation and economic requirements. Call your nearest Rome Cable salesman today for help in selecting the precise cable you need.

*Name of mine furnished on request.

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WHO'S DEDICATED TO YOUR JOB
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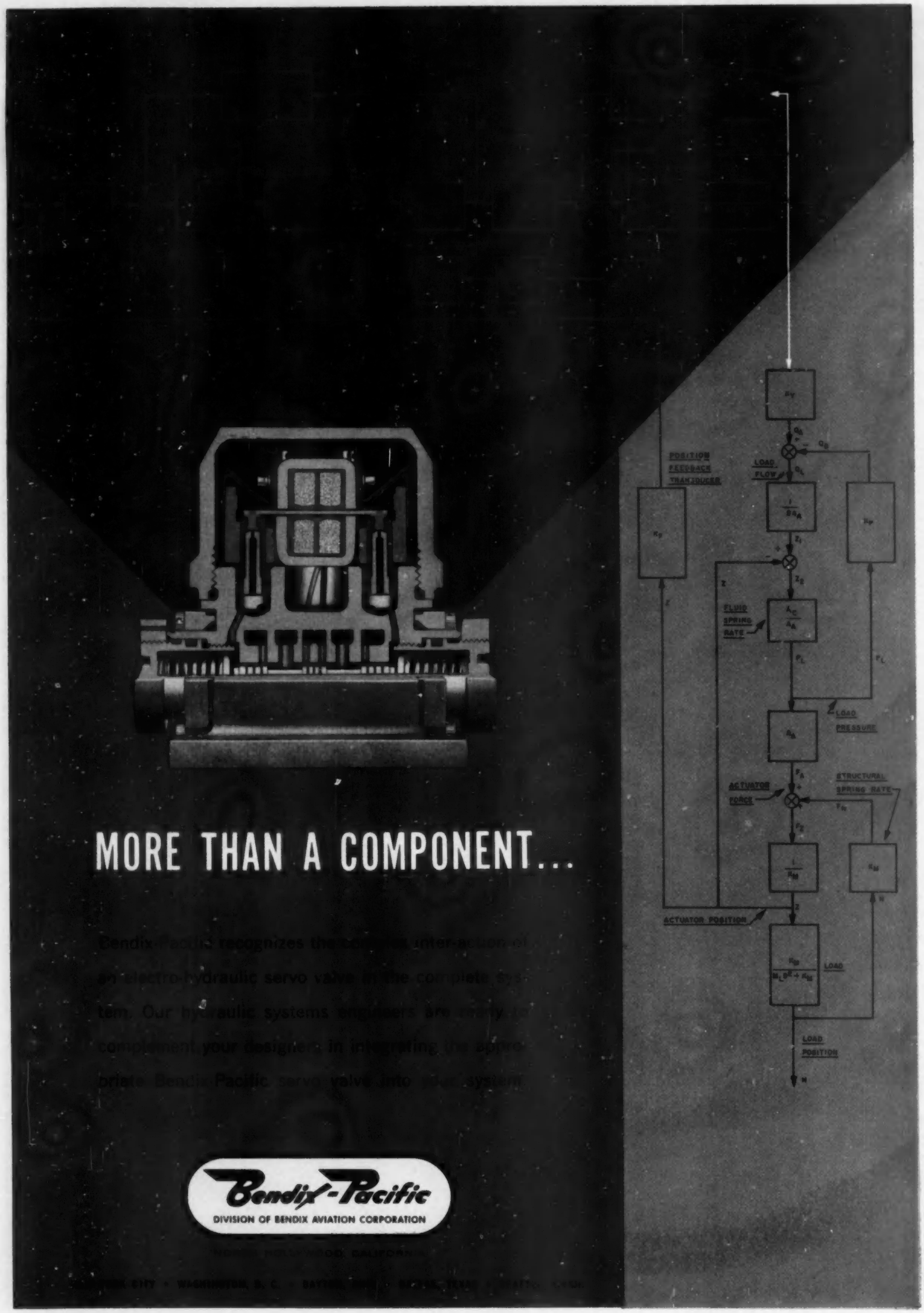
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Newsbreaks In Control

SOIND SCRUTINIZES COMPUTING-CONTROL

Whiting, Ind.—Standard Oil Co. of Indiana is experimenting with both closed loop and open loop computing-control at a crude oil distillation unit. But SOIND is moving cautiously. Proposed plans: to operate open loop with a centralized computer, existing IBM equipment; to run closed loop with localized, special-purpose computing equipment. One SOIND research engineer leans toward open loop control. He feels it might allow processing units to be connected in switchboard fashion to a centralized computer. By pressing a button, an operator could learn the status of any refining unit, could then make necessary adjustments. One large computer, he hypothesizes, would be more reliable, easier to maintain, than many small machines.

SWISS ANALOG COMPUTER FOR U. S.

Hatboro, Pa.—Analog computer equipment built by Guttinger Co. of Switzerland (CtE, Feb. '59, p. 40) will be marketed in the U. S. by Boonshaft and Fuchs Inc. First Guttinger analog computing facility will be established at B&F's Hatboro plant. The Swiss company concentrates in the low-to-medium cost field. Typical of the Guttinger line: a general purpose, 12-amplifier, analog machine, said to have an accuracy of 0.3 percent and costing about $2,200.

TAPE TESTER GAGES CYLINDRICAL SHAPES

Dayton, Ohio—Sophisticated magnetic tape-controlled gage is being developed by Sheffield Corp., Div. of Bendix Aviation Corp. to speed the accurate machining of missile parts. The device is a five-axis, internal-external gage for measuring cylindrical shapes. The tape contains the exact linear size information for any given instant and position along the major axis of the cylinder; it programs two styli (one internal, one external) to compare what the actual dimensions are with what they should be, and the device reads out deviations of a few millionths of an inch. Four tape channels direct in-out motion and the lateral movement of each stylus.

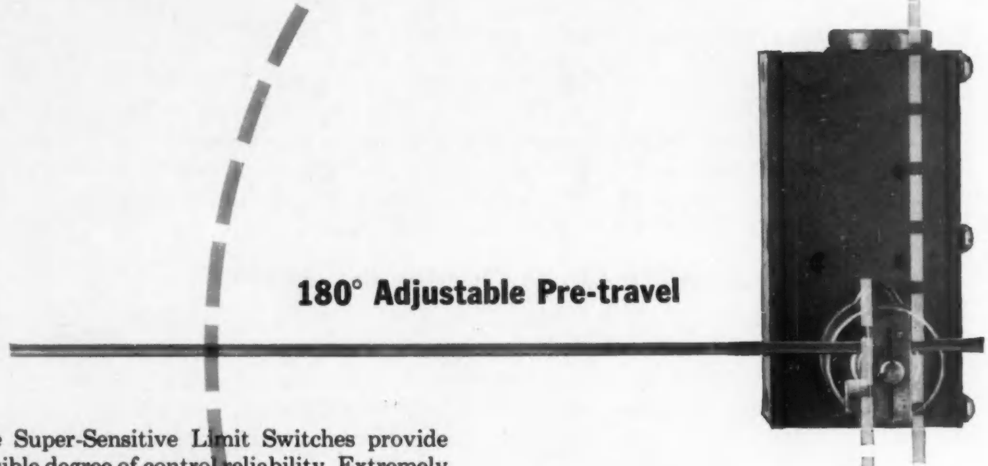
NASA TO STUDY DIGITAL CONTROLS

Cleveland—National Aeronautics and Space Administration has awarded a $178,000 grant to Case Institute of Technology associate professor Harry W. Mergler to investigate the use of hybrid numerical circuitry in closed-loop control systems for space applications—primarily guidance systems. The fundamental study will probe how special purpose digital data processing equipment man be incorporated into control loops operating in real time. Digital controls will enable spacemen to put data transmission, telemetry, and control signals into a common language as well as allowing higher resolution. The work will be done at Case's Numerical Control Laboratory.

RCA, FOXBORO SIGN COMPUTING-CONTROL PACT

Camden, N. J.—Radio Corporation of America has announced a new computer system, the RCA 110, designed for industrial process control. To help market the new machine to process users, RCA has signed an agreement with instrument and controls maker, The Foxboro Co. Under terms of the pact, the two companies will cooperatively develop fully integrated industrial control systems, linking the RCA computer with Foxboro's fully electronic instrumentation. RCA will service the machines after installation. The new RCA 110 is fully transistorized, and it has both drum and core memories.

LIMIT SWITCHES WITH 1½" OUNCES SENSITIVITY... IMMUNE TO VIBRATION



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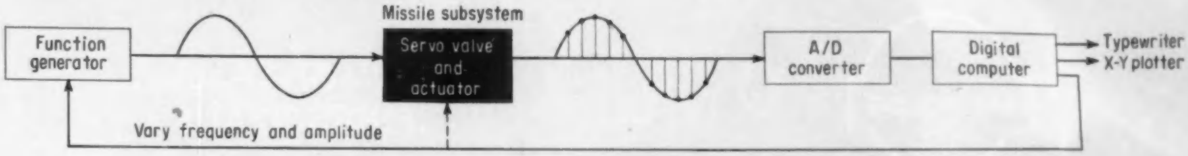
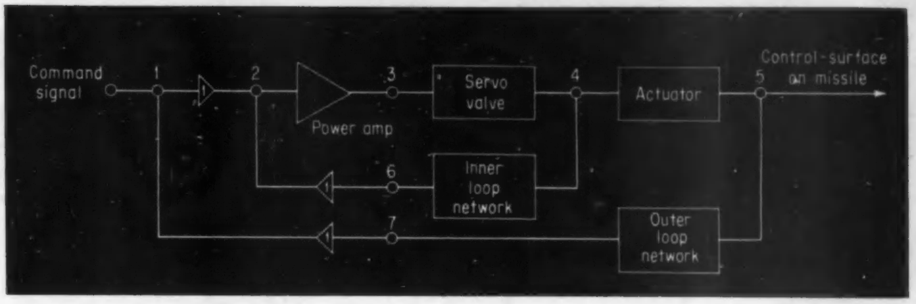


MISSILE SUBSYSTEM



Computer Tests Dynamics of Missile Controls

Digitally-directed test system will automatically program, calibrate, generate driving signals, and analyze frequency-response test for missile servo systems.

SANTA MONICA, CALIF.—Douglas Aircraft Co. will install a general-purpose digital computer to automatically perform dynamic response tests, both open- and closed-loop, on missiles subsystems. In particular, the computer-directed test setup will rapidly and routinely plot frequency-response diagrams (Bode plots) of servovalves and actuators positioning the control surface of a missile. Tests will be run under stiff environmental conditions, simulating actual missile flights.

The installation will drastically cut manual testing time; what now takes one to four hours manually will be accomplished by the computer in three to five minutes. A study for economic justification indicated that the $200,000 expenditure for the computer and accessory test equipment would be quickly regained by such a reduction.

And other advantages will accrue, too, say Douglas Testing Div. engineers. "The test system will yield results in final form, accurate to 1 percent compared with the present 10 percent, ready for analysis by the design engineers concerned with improving the servo's performance. Probably the most significant advantage of using the digital computer in this way is that successful development of missile subsystems can be completed two years earlier than planned."

The heart of the automatic dynamics testing system is an RW-300 digital computer, an 8,000-word, drum-memory, flexible-program machine purchased from The Thompson-Ramo-Wooldridge Products Co. Because of the computers's automatic and flexible operation, Douglas engineers—who will be trained by TRWP to program the computer—can easily change their testing procedure as they gain experience.

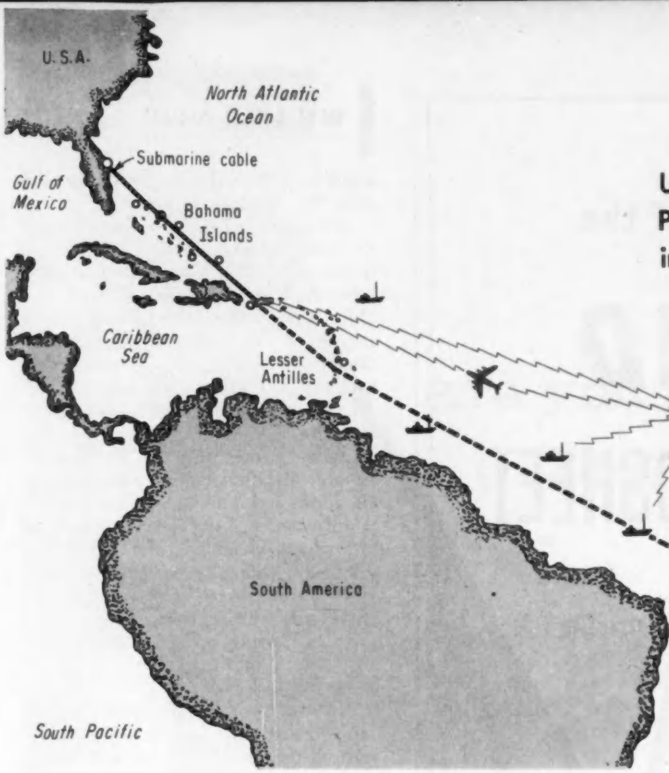
The upper diagram shows the basics of the testing system. A Hewlett-Packard 202 function generator will supply input signals over a range of 1 to 200 cps. An X-Y plotter at the computer output will plot both amplitude ratio and phase angle vs frequency—plots will be made at five to eight input amplitudes to check the effect of subsystem nonlinearities. At each frequency the computer will sample output amplitudes, perhaps 30 samples taken at equal time intervals over one or more cycles. The computer will then perform a Fourier analysis of the data, computing the fundamental frequency of the usually distorted output, and, from this, the amplitude ratio and phase angle.

In addition, the RW-300 will take the logarithm of the amplitude ratio so that the plot can be printed on a decibel scale. Calculation for one point takes about ½ sec. About 30 such points at one amplitude will comprise a frequency response test, although the actual number will vary. Gain-margin tests will also be performed by automatically increasing loop gain until oscillations occur. The oscillation frequency, calculated by the computer, will then be recorded on the frequency response graph.

Besides performing the necessary calculations, the computer will also program-control the entire test operation. As an example, the computer will adjust and measure the function-generator frequency to as small an increment as 0.01 cps, calibrated against the drum speed. The computer will sequence relays to switch in various sections of the subsystem (as shown in the lower diagram) for periodic calibration by the test system. The primary function of the test system is to carry out frequency-response test between terminals 3-4, 4-5, and 3-5.

Because of the favorable relationship between testing time (5 min) and setup time (1 hr), the computer test system may eventually be shared by 10 remote testing stations. With such savings possible, enthusiastic Douglas engineers already visualize similar dynamic checkout systems on the production line and for missile preflight tests.

—Harry R. Karp



Use of aircraft to collect and retransmit Pershing test data from downrange tracking ships may cut result recovery lag.

Will Mid-air Relay Speed Pershing Test Data?

CAPE CANAVERAL—Readying data facilities for the first tests of the Army's Pershing surface-to-surface missile, Atlantic Missile Range engineers are considering the use of telemetry-carrying aircraft as airborne relay stations to speed test data from tracking ships spotted over the lower Atlantic Ocean. Telemetry airplanes are not new, but missile engineers have never used them to their full capability for a variety of reasons—technical and economic. Now a new data format may make aircraft middlemen feasible.

For missile shoots that pass over and impact within range of island tracking stations as far south as Puerto Rico, there is no problem. Data are translated on the island and transmitted rapidly back to the Cape by way of submarine coaxial cable. For example, impact prediction data from island FPS-16 radars are carried back in real time to a Cape-based IBM 709 computer.

• **Delay in the South Atlantic**—If a shoot impacts in the South Atlantic beyond Puerto Rico, however, trajectory and telemetry data are received on tracking ships. At present, such data are recorded on magnetic tapes, which are brought to shore after the test; the tapes are then flown to the Cape for data reduction. A ship well down the range, deep in the South Atlantic, might cruise for five days getting back to where a plane can pick up the tapes. That means data processors in Florida have to wait a week or more before they can start reducing the information. Playback over high frequency radio is unsatisfactory because the transmission rate is limited by multipath effects.

The new scheme will cut the wait for downrange data to one day, might even slash it to hours. The bright possibility: after missile splash, the ship would telemeter its data to an airplane, which would then retransmit it to the nearest island station on the submarine cable. Next, the data would be relayed over the submarine cable to the Cape. The main restriction to such a setup at present is that the telemetry band is too wide for the bandwidth of the submarine cable. To overcome this in the Pershing tests, engineers propose using a form of Pulse Code Modulation telemetry that will meet the bandwidth limitations of the cable. It will resemble the system already working to return impact prediction data.

• **New digital format**—The present impact prediction system takes data from rotary shaft encoders on the FPS-16 radar. The data are strobed ten times per second into adjacent core shift registers, sequenced out serially, intermixed, and transmitted as shaped tone bursts at 1,000 pulses per second rate over the cable. The same procedure would be followed for key trajectory data generated on the ship: seaborne FPS-16 radar data, ship position from Loran navigation system, and ship heading and attitude data from two independent gyro systems. Each of these four pieces of data would be sampled ten times per second, then stored as a series of shaped tone bursts on four channels of a seven-channel magnetic type recorder. Coded range timing would be recorded on a fifth channel. In this

condition, the data can be transmitted over the submarine cable.

If the aircraft were in line of sight of both the ship and the island, the airborne telemetry equipment could retransmit while receiving from the ship. To do this, the aircraft would require two antennas, rather than the one now installed, and a considerable increase of power. In addition, if direct relay of data is to become a standard part of test procedures, the altitude of operation of the aircraft should be raised considerably, posing an additional problem unless jet aircraft were used. If jets become the airborne middlemen, the Air Force may have difficulty in keeping them aloft during long holds that occur, particularly during the early part of a missile's testing program. But, obviously, none of the problems is insurmountable.

None of the present proposals go so far. Present plans call for ships transmitting the data to the aircraft, which would fly the tapes to island stations rather than retransmitting. But even this technique will deliver data back at Cape Canaveral on the same day the missile is launched. Decision on whether to use this approach or not will be made within the next six weeks.

—Douglas Dederer

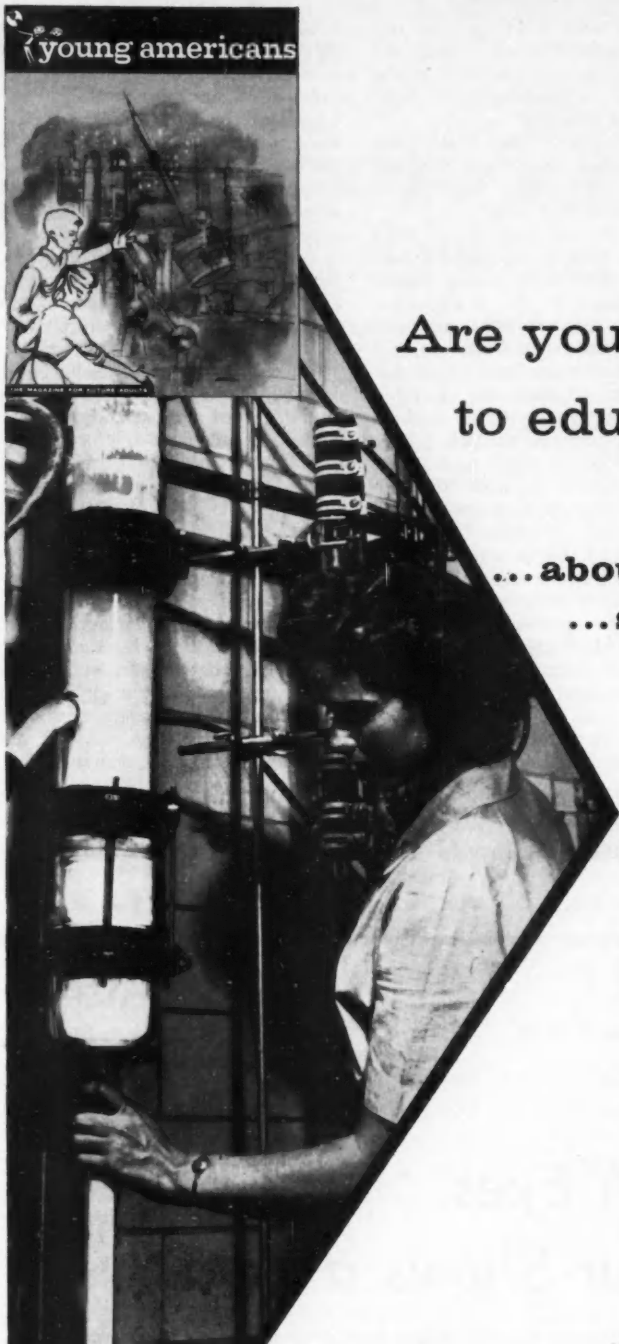
Electronic Post Office

New post office being built at Oakland, Calif., will try some new electronic devices, pushing post office modernization still another giant step ahead.

WASHINGTON—

Last month, Postmaster General Arthur E. Summerfield called in the press to announce additional modernization plans for the Post Office Department. Already well advanced into its first real modernization program in history (CtE, May, '59, p. 22), the Post Office is now accelerating the pace. Summerfield announced the start of work on another completely mechanized post office, this one to be built in Oakland, Calif., and he showed off some radical new designs under study for the future.

For the entire West Coast, the Oakland construction will mean a major



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speedup in mail handling. The new post office, called Project Gateway, will serve as a laboratory for some of the new electronic devices being developed for the Post Office.

Food Machinery Corp. is still planning the actual equipment that will go into Project Gateway. Likely to be incorporated in the project:

▶ the first semi-automatic letter sorter to be built in the United States (the Post Office is now using Dutch-built machines at its Washington, D. C., installation). The machine, built by the Burroughs Corp., can sort up to 3,000 letters an hour to 300 destinations. It requires one operator. Burroughs designed it in modular form so that it can be enlarged to handle the loads at bigger post offices.

▶ an automatic machine for reading and sorting envelopes, developed by Intelligent Machines Research Corp. Although the present machine, which uses optical scanning, can only read typewritten addresses, it encompasses two new approaches, says its inventor, David H. Shepard. First, it covers an all-electronic extension of stroke recognition, previously patented by Shepard. And secondly, it also uses a "tapped delay line" or "shift register" approach to character recognition. This scheme involves introducing the output of a scanning mechanism, such as a flying spot scanner or magnetic head, into the first stage of a tapped delay line or shift register. Recognition is accomplished by combining the outputs of selected stages with appropriate circuitry to sample at one point in time signals, which were applied to the delay line at different points in time. In this way, says the inventor, the device can recognize a character regardless of where it is positioned as long as it is entirely within the scanning field.

▶ new high speed letter facer-canceler developed by Pitney-Bowes. The unit displayed consisted of three machines in tandem, each processing up to 500 letters per minute. In a recent experiment, a six-member crew was able to handle 27,000 letters per hour with the tandem machine, in contrast to the 16,000 per hour processed by conventional equipment manned by a twelve-man crew.

Attractive as these new devices were, they were upstaged by some really revolutionary designs still on the drawing boards. For example: circular mail sorters, automatic readers capable of identifying handwritten addresses, and fully automatic parcel post sorters.

Proposed Schedule of Conferences and Exhibits

	Jan.-Feb.	Mar.-Apr.	May-June	Sept.-Oct.
1961	St. Louis	Pittsburgh	Toronto	Los Angeles
1962	Boston	Dallas	Seattle	Cleveland
1963	Los Angeles	Atlanta or Jacksonville	Detroit	New York
1964	San Francisco	Houston	Twin Cities	Philadelphia
1965	San Diego	Pittsburgh	Montreal	Chicago

ISA Eyes Four Shows a Year

The proposed schedule above is indicative of a major change in exhibit planning by the Instrument Society of America. Starting in 1961, ISA will sponsor four shows and conferences a year, instead of one annual show.

Object of the increase of conclaves, with a wider distribution of locations, is to bring the exhibit (and conference) closer to ISA members. ISA executives expect an increase in total attendance as a result of cutting down travel distances and costs.

Most exhibitors queried about the proposed change like the idea. One problem ISA executives may have is getting enough good technical papers to fill four meeting programs. ISA sections have already accelerated their planning activities to meet the demand. The proposed schedule now has to be approved by the membership.

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IN536	50	35	50	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	400
IN537	100	70	100	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	400
IN538	200	140	200	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN539	300	210	300	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN540	400	280	400	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN1095	500	350	500	750	500	250	15	−65 to +165	−65 to +175	1.2 at 500 ma	5	300
IN547	600	420	600	750	500	250	15	−65 to +165	−65 to +175	1.2 at 500 ma	5	350

6 Types for MAGNETIC-AMPLIFIER applications requiring exceptionally low-leakage currents

IN440-B	100	70	100	750	500	250	15	165	−65 to +175	1.5 at 750 ma	0.3	100
IN441-B	200	140	200	750	500	250	15	165	−65 to +175	1.5 at 750 ma	0.75	100
IN442-B	300	210	300	750	500	250	15	165	−65 to +175	1.5 at 750 ma	1.0	200
IN443-B	400	280	400	750	500	250	15	165	−65 to +175	1.5 at 750 ma	1.5	200
IN444-B	500	350	500	650	425	0	15	150	−65 to +175	1.5 at 750 ma	1.75	200
IN445-B	600	420	600	650	400	0	15	150	−65 to +175	1.5 at 750 ma	2.0	200

EXTENSIVE TESTING ASSURES RELIABILITY AND LONG LIFE in these 13 welded, hermetically sealed Silicon Rectifiers designed and produced by RCA.

- 100% high-temperature dynamic test at full load current and rated voltage
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- 100% pressure-seal test
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For information concerning the full line of RCA Silicon Rectifiers and their special applications, contact the RCA Field Office nearest you. For technical data, write RCA Commercial Engineering, Section J-56-NN, Somerville, New Jersey.

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One synchro serves equally well as transformer, torque receiver, or torque or control transmitter.

The Universal Synchro—

Ready for Test

PHILADELPHIA—

Frankford Arsenal's dream of standardized control components (CtE, July '58, p. 26) moved a step closer to reality last month with the announcement that a "universal" synchro had been put into test. The new unit is designed to serve equally well as control transformer, control transmitter, torque receiver or torque transmitter. Presently, each of these functions call for a distinctly different type of synchro—a circumstance that raises costs, complicates inventory control, and increases the job of spare-parts stocking.

The universal synchro features five independent sets of windings, which are brought out to a printed circuit terminal board on the end of the housing. All it takes to adjust the unit for a particular mode is to loosen a screw and turn the terminal end cover to the desired position.

The synchro under test is a size 23 (2.25-in. diameter), 400-cycle unit designed by the Ketay Dept., Norden Div., United Aircraft Corp. It is $\frac{7}{8}$ in. longer and 4.5 oz heavier than equivalent conventional units.

Evaluation will require about eight months. If the 400-cycle size 23 proves out and is given official military acceptance, Norden will go on to other sizes and frequencies.

Frankford Arsenal has also commissioned Norden to study feasibility of a size 5 ($\frac{1}{2}$-in. diam) synchro. The size 8 (0.75-in. diam) is smallest unit now in production. Preliminary mod-

els of size 5 indicate that main obstacle will be learning to handle the extremely fine No. 44 wire required for the windings.

Other Frankford-sponsored feasibility studies underway cover size 11 components; components for two high temperature ranges (up to 300 deg C and from 500 to 600 deg C); synchros accurate to plus or minus 2 min; and high-torque units developing as much as 200 percent above the present standard torque ratings.

Oil Men Talk Computers and Remote Control

Two of the hottest subjects in control in the oil industry these days are sophisticated remote control of tank farms, pipelines, and lease automatic custody transfer and the application of computers to distribution and refining.

LONG BEACH, CALIF.—Oilmen took a long hard look at some of the new techniques of control during the American Institute of Electrical Engineers Sixth Annual Conference of the Petroleum Industry. The two techniques that bore the brunt of their scrutiny: sophisticated remote control of production and transmission operations and use of computers in refining and pipeline applications.

E. G. Warren, Humble Oil and Refining Co., emphasized the practical aspects of remote control of a refinery farm in Baytown, Texas. He pointed out that environment—the humid Gulf Coast atmosphere buttressed by salt spray—was a major problem, dictated the use of special components such as hermetically sealed relays. Because of such considerations in this installation, Humble has operated the semi-graphic panel system for three years with very little maintenance and no periodic replacement of parts except lamps.

• **Fast supervisory control**—A solid-state supervisory control system, typical of the installations causing a lot of interest in the petroleum industry, was described by G. H. Beck, Conti-

nental Pipeline Co. It transmits data by a binary coded decimal, serial-by-bit form with a minimum of three digits of 5 bits for each command, indication, or other function. Since information is not transmitted by signal strength or amplitude, accuracy is maintained over long transmission distances.

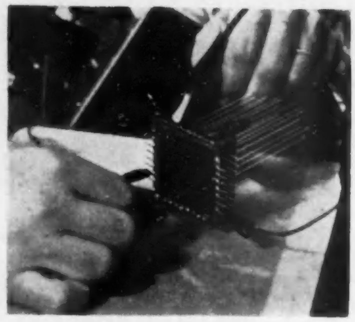
In the system, which extends from Oklahoma City to Wood River, Ill., information is digitized as soon as possible. The analog-to-digital conversion system requires one converter per station. The converter compares the analog output from each transducer with known current levels for each digit of information on a binary basis as percent of full scale output. High speed transistor switching converts in one-third of a second.

With proposed additions, the system will handle 51 three-digit pressures and speeds, five four-digit meter readings, eight product indicators, 12 load controls, 35 pump starts and stops, 99 alarms, 15 valve open-closes, and 17 miscellaneous commands. Controls are carried over a single party-line telephone circuit.

Time for scanning a complete cycle is under six seconds; data are transmitted about every 30 secs. At a master station, pressure, speeds, delivery meter readings are automatically logged on the hour. The operator can obtain a printout at any time by pushing a button. In addition, a small "deviation printer" writes out all readings which have changed from the last record.

• **Computers from a user**—Discussing the application of computers at several levels, J. T. Manry, Tennessee Gas Pipeline Co., issued a warning to potential computer users. His warning: don't accept theoretical conclusions whose validity cannot be fully ascertained until after the die is cast and the system is operating. He also expressed concern about the rapid rate of obsolescence of computer equipment. His recommended approach for pipeline operators: a phasing-in to get experience before jumping to all-out computing-control.

• **Computers from a maker**—General Electric Co.'s E. B. Turner had a more positive view. He felt that the use of computers would grow rapidly in the calculating and controlling of feeds into and out of processing equipment and wherever logic decisions are required for efficient refinery operation. Turner said that any process whose product output was over $3 million was a good candidate for computing-control.



Glass rod memory under test.

Glass Rods Make Unusual Memory

First computer memory with thin film glass rods instead of cores will be delivered to Naval Ordnance Test Station. Its speeds can be four times those of a conventional core memory.

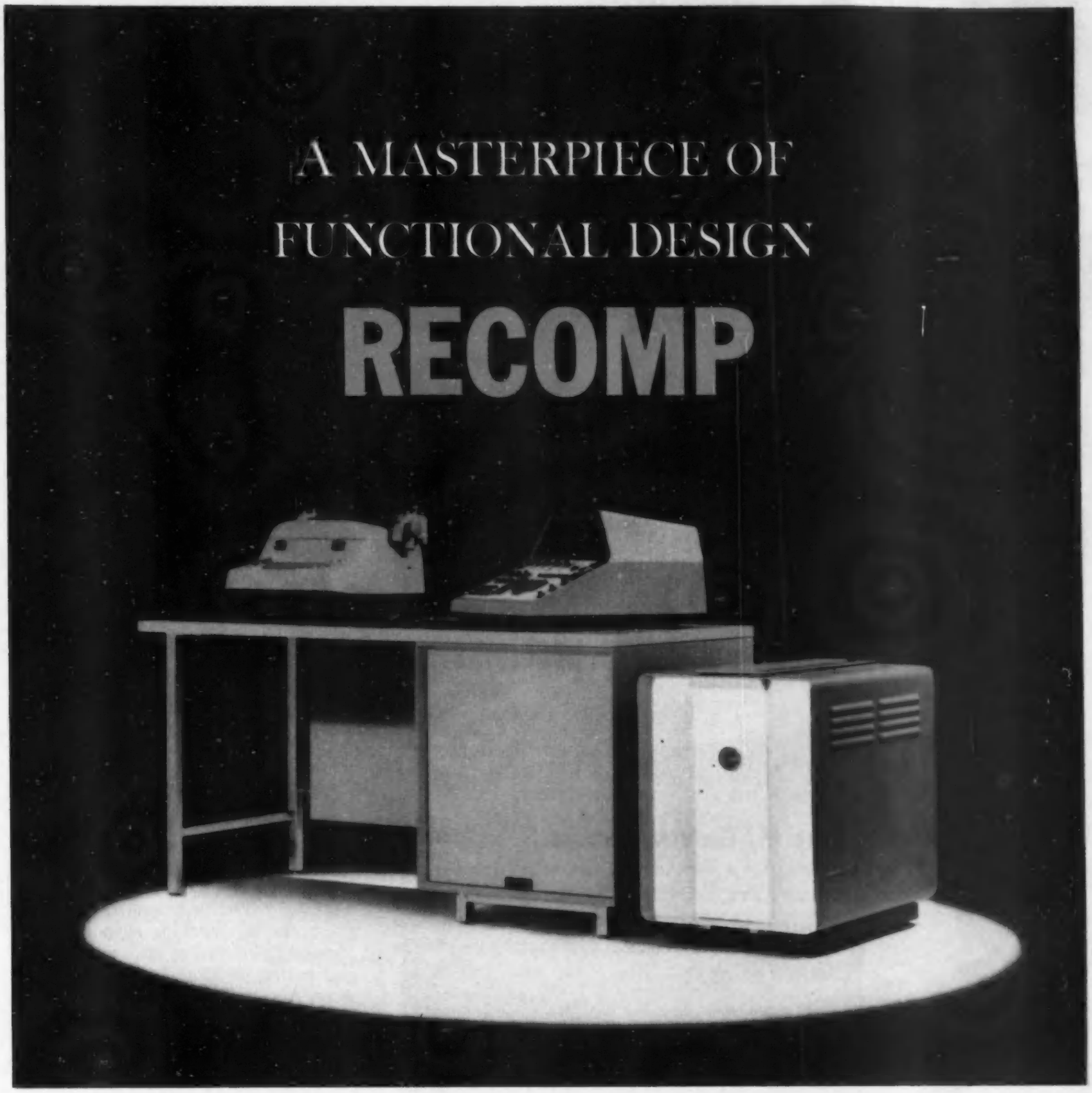
LOS ANGELES—

A glass rod computer memory, like the one pictured above, will be delivered later this year to the U. S. Naval Ordnance Test Station at China Lake. Although it will be comparatively small—only 768 bits—it will serve as a computer buffer memory for the sequencing and control of NODAC (Naval Ordnance Data Automation Center), replacing a number of high speed flip-flop registers. The unit will be built by the Electronics Div., National Cash Register Co., which developed the glass rod concept. Overall size of the storage portion of the unit: a cube block about 2¼ in. on a side.

NODAC is a general purpose data reduction machine; it can accept ten voltage inputs simultaneously with maximum conversion rates of 44,000 per sec. The machine has 270 flip-flops available for logic operations and is tied into, and under the control of, an IBM 704 computer.

NOTS engineers expect the new high speed glass rod memory will enable NODAC to tackle a number of real time problems that can't be solved now. In addition, they feel the new units will permit sophisticated modifications of control circuitry at a moderate cost.

• **Glass rod heart**—The key to high speed operation of the new NCR



COMPACT...VERSATILE...EASY TO OPERATE

The RECOMP computer strikingly demonstrates the four basic principles of design excellence: performance, ease of operation, ease of maintenance, functional styling. It is a masterpiece of practical design.

The magnetic disk memory contains 4096 words, each of 40-bit length, or 12 decimal digits, eight alpha characters, or two program instructions. It retains as many as 8000 instructions or stores more than 49,000 decimal digits of data. Reading speed of the photoelectric tape is 400 characters a second. The exclusive digital readout flashes arabic numerals to reveal contents of any word or register.

RECOMP gives you far more capacity, versatility, and trouble-free service for your money. It's available now—for outright sale or at a moderate monthly rental that includes maintenance. *And there's no extra equipment to buy...no cost of installation.* For information on how RECOMP can solve *your* problems, write Autonetics Industrial Products, Dept. 310, 3584 Wilshire Boulevard, Los Angeles 5, California.

Digital computers by Autonetics

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memory is a long, thin, magnetic-coated glass rod—with a 10 mil diameter—with a solenoid wire winding. To make these units, NCR first coats the glass rod with a silver conductor, then electroplates a thin magnetic alloy of iron and nickel. At each preselected bit position, four successive, single layer, solenoid windings—two input, a sense, and an enabling winding—are superimposed over the rod.

The rod exhibits the same general electrical characteristics as a toroidal magnetic core. But the unique construction makes the rod a continuous magnetic medium so it can store many bits of information in a single unit. The memory can be built-in quickly by simply threading the rods through previously assembled matricies.

• **Rods versus cores**—NCR claims that the glass rod memories will match or outperform magnetic cores in all applications except magnetic amplifiers. They say that the rods can operate in a broader range of temperature as well as at much higher speeds. And rod memories are comparable to core units in cost, speed of fabrication and test, and maximum memory size. This last claim is strengthened by an NCR proposal for a 300,000-bit memory for a military installation.

Although pleased by the reception of engineers at NOTS, NCR feels that some of the most significant applications of its glass rods may still be in the laboratory. It has great potential as a versatile computer element. For example, switching elements that operate at speeds of two megacycles and better are close to the hardware stage. Also under study: glass rod shift registers and counters, which operate in the two to four megacycle range.

—Michael Murphy
McGraw-Hill News

PROGRESS REPORT:

ANIP Program Expands to Surface & Subs

DALLAS—

When the Army-Navy Instrumentation Program (ANIP) started in 1953, the objective was to bring the cockpit of the airplane up-to-date, harnessing the newest techniques of electronic sensing and data processing.

NEW

CARRIER AND LOW LEVEL PREAMPS OFFER MORE RECORDING USEFULNESS

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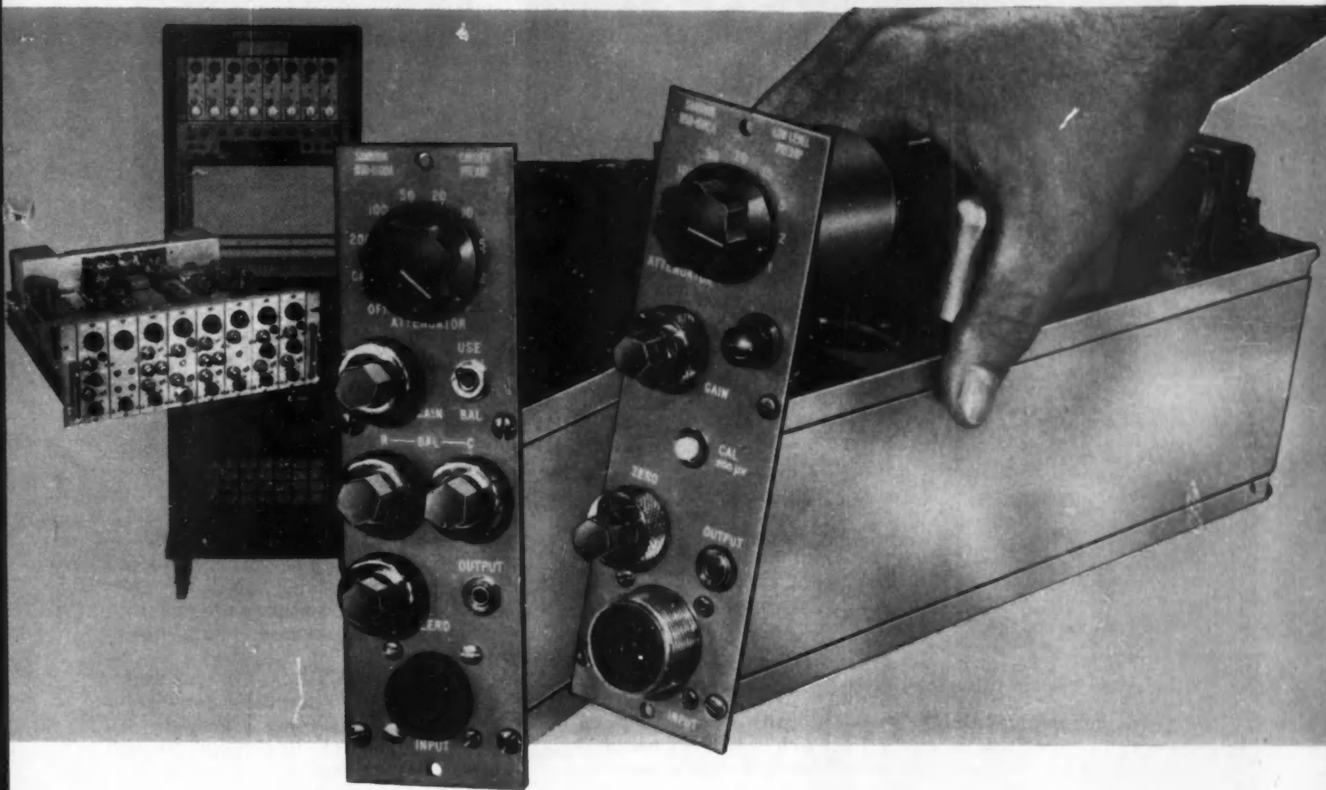
—per dollar
—per channel



WITH the availability of these two new plug-in preamplifiers and associated MOPA, Sanborn 6- and 8-channel "850" oscillographic recording systems can now record an even *wider* variety of inputs — wherever *many channels* are needed in *minimum panel space*, with *no* sacrifice in system accuracy or reliability. The 850-1100A is a carrier amplifier-demodulator unit designed to work with resistance bridge, variable reluctance and differential transformer transducers. Attenuator, smooth gain, position and balancing controls are on the 2″ x 7″ front panel; input and output connections are provided at both front and rear. The 850-1500A is a chopper amplifier with floating input isolated from a floating output, capable of measuring low level DC-100 cps signals such as those from thermocouples and strain gage bridges. Design provides low noise operation, greater freedom from ground loop interference and high common mode rejection ratio. Required carrier excitation (2400 cps standard, 600, 1200 and 4800 cps optional) and chopper drive (440 cps) voltages are supplied by the 850-1900 MOPA, a dual-oscillator unit which can handle up to eight of each preamplifier.

SPECIFICATIONS

	850-1100A	850-1500A
Sensitivity	100 µv in gives 1 v at output	
Input impedance	approx. 2500 ohms	approx. 100,000 ohms
Output	±2.5v across 3300 ohms	±2.5 volts across 2500 ohms
Freq. response	−3 db at 20% of carrier freq.	0–100 cps, −3db
Linearity	±0.5% of full scale	±0.1% of full scale
Common mode performance		120 db for 60 cps, 160 db for DC with 5000 ohms unbalance in input
Noise		2 µv p-p over 100 cps bandwidth

(data subject to change without notice)

Ask your Sanborn Sales-Engineering representative for complete facts on all "850" system units — or write the main office in Waltham.

SANBORN COMPANY
Industrial Division
175 Wyman St., Waltham 54, Mass.

NEREM '59 COMM. ARMORY, BOSTON, NOVEMBER 17, 18, 19.

Douglas Aircraft's proposed cockpit mockup. Pushbutton controls make the pilot's job easier.

Last month, at a special ANIP symposium here, contractors in the program reported on progress made to date. The report indicates that ANIP has turned into a search for a balanced man-machine partnership for the all-purpose operation of air, surface, and sub-surface craft.

Item: The ANIP sister program, Submarine Integrated Control (SUBIC), has found instrumentation features developed by ANIP for aircraft are logically adaptable to atomic-powered submarines featuring one-man control.

Item: One ANIP goal—a simplified all-purpose instrumented cockpit for fixed winged craft and helicopters—is still five years off. By-products of the program, however, have been put to use by builders of missile control and air and ground defense systems.

Coordinators of the aircraft program, Douglas Aircraft for fixed wing and Bell Helicopter Corp. for helicopters, unveiled what has transpired since the last public showing of ANIP equipment almost two years ago (CtE, Dec .'57, p. 29). Both have built new mock-ups of proposed cockpits for all-weather flying, using the contact analog display.

• **Douglas checkerboard**—Douglas' instrument, developed by the General Electric Co., shows the pilot a checkerboard ground image. A computer-determined path for the plane appears on a transparent windshield. The present model (see picture) shows the earth as a flat surface, but an advanced version to be test-flown within a year will show real terrain in addition to the flight path.

Bell has built an experimental helicopter equipped to give a pilot synthetic information on a contact analog display for all-weather flying. In this

Ceramo® Thermocouples "Tortured" By Exotic Fuel Explosions At Air Reduction Co.

Metal "bomb" designed by Airco for testing liquid fuels showing "Ceramo-Couple' and gas escape line.

Airco furnace containing molten metal—with test "bomb" ready for immersion.

When Thermo Electric designed "Ceramo" for extra-tough thermocouple applications, even "Ceramo's" designers did not figure on the "torture test" devised for it by Air Reduction Co. High temperatures, extreme corrosion, high pressure, great durability, easier installation—all these conditions "Ceramo" takes in stride with typical versatility. But ability to withstand actual explosions—well, that was a lot to ask. "Ceramo," however, did just that.

Airco needed such a thermocouple to test thermal stability of rocket and jet engine liquid propellants at their Murray Hill, N. J., laboratories. The fuel is placed in a small metal vessel which is then immersed in molten metal. One opening of the vessel is sealed with a small rupture disc. In the other opening a thermocouple is fitted to measure the reaction rate of the fuel over a wide range of temperatures before explosion occurs. Naturally, the thermocouple must withstand the explosion. "Ceramo-Couples" withstand 10 or more such explosions before replacement. This "torture test" is endured by enclosed junction "Ceramo-Couples" of but 1/16" o.d. with 30 gage conductors. This test method would not be feasible without thermocouples of such small diameters.

Other "Ceramo" features essential to this job include accuracy—to indicate exact temperatures; sensitivity—to indicate temperature changes quickly; and corrosion resistance—these exotic fuels are highly corrosive.

"Ceramo" could well be the answer to your thermocouple problems—mechanical, thermal or chemical. Find out by contacting Thermo Electric today.

Write For Bulletin 325-B.

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY
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CIRCLE 43 ON READER SERVICE CARD

design a combination optical-mechanical system generates grid-type ground patterns. The image is displayed on a 16-inch transparent glass screen—a trichroic mirror built by Autonetics Div. of North American Aviation—placed in front of the pilot.

• **Bell's simulator**—The helicopter company also reported that its proposed simulator has been built and is at work in human engineering studies. The simulator produces the motion, sound, vibration, and general cockpit arrangement of existing helicopters. Bell expects the simulator will permit the evaluation of instruments and controls, developed for the ANIP program, before their actual installation in helicopters.

In the simulator, a computer accepts signals generated by the pilot as he moves control levers. The computer then calculates the response of the helicopter and these responses cause a moving platform to simulate the movement of the helicopter. In addition, the computed responses drive a display generator which presents a visual picture to the pilot, describing his altitude, velocity, and attitude.

Probably one of the biggest developments to come out of ANIP in the past two years has been the progress made in building transparent television tubes. In ANIP cockpits, the pilot has a choice of looking through his cockpit windshield or of switching to viewing through the analog contact display.

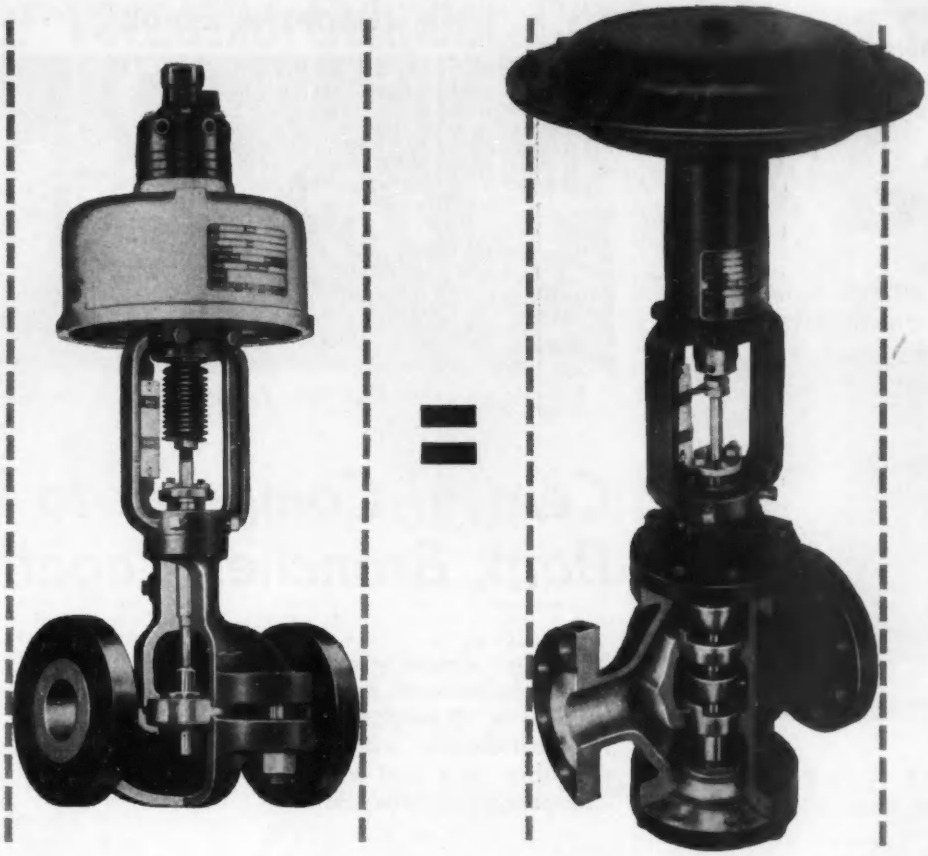
Refinements of the Kaiser-Aiken thin cathode-ray tube have now reached the point where the tube can be built from ordinary half-inch plate glass. Such construction is easier to fabricate and improves the optical qualities of the tube.

Other developments:

▶ New air velocity sensor for helicopters has been proposed by Midwest Research Institute. The acoustic-electromagnetic device would make indirect measurements.

▶ First phase of an obstacle-sensing program has been completed by Research and Development Div., Allen B. duMont Laboratories, Inc., with T.R.G. Inc. It indicates that an advanced radar-type system is the most feasible solution to the obstacle sensing program.

The ANIP program is being sponsored by the Office of Naval Research. It was reported in Dallas that almost $17 million has been spent so far on the program. ONR expects the next year's budget will at least match this year's, and will probably be increased.



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With face-to-face dimensions to I.S.A. standards, K&M split body valves are interchangeable with K&M regular globe-body diaphragm valves (and with all standard makes of diaphragm valves).

This *exclusive* feature of the K&M split body design enables you to make significant reduction in your plant inventory investment of replacement valves. It gives you highly desirable flexibility.

Additional flexibility is provided in the K&M split body valve itself. Interchangeable. unitized construction makes it possible to develop 432 different valve combinations from a single split body.

In a matter of minutes you can make the body reverse or direct-acting; switch the operator to dome, diaphragm, or handwheel; change the seat ring to one of several types; recharacterize by selecting a different plug; substitute the replaceable, rotatable flanges; convert from globe to angle type.

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CIRCLE 45 ON READER SERVICE CARD

EUROPEAN REPORT

Barclays Bank will tie an EMIDEC 1100 to 15 branches

Central Computer to Tie Bank Branches Together

One large computer will centralize the accounts and bookkeeping of 15 bank branches. The installation will reduce the labor force and will save storage space in the branches

LONDON—Barclays Bank Ltd., one of London's leading financial institutions, has announced plans for the first computer application in British banking circles. The system will tie by teletype, 15 downtown branches to a transistorized EMIDEC 1100 computer, made by EMI Electronics Ltd. Cost of the completed system is estimated at $600,000, of which the computer represents $375,000. The banking net is to be operational by 1961.

The central computer will perform three main tasks each day: at noon, it will update all accounts with items that have been cleared by England's check clearing houses; at 3:30 in the afternoon, it will debit accounts for checks drawn against them throughout the day; and it will print out monthly statements for the 40,000 accounts handled by the system. All this will take only three hours a day. Remainder of the computer time will be spent performing statistical and economic calculations for the bank's staff.

• **Updating accounts**—In the morning the branches will transmit, via teletype information from the checks received from the clearing houses. A tape attachment on the listing-adding machines supplies the input, so that the tape preparation is a byproduct of normal branch office procedure. The data are sent to the computer in a 20-character code which is split into three blocks. The first block (four characters) conveys the check number and an identifying symbol to show whether the entry is to be added or subtracted from the account. In the second block are the account number and a symbol indicating an original or correcting entry on the account. The final block carries the check amount and an end-of-entry signal.

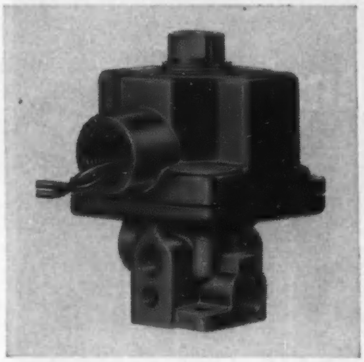
At the computer center, data from the branches are perforated onto input tapes for the computer. The list of items is sorted and placed into account number sequence by the computer; then each entry is used to update the master records which are maintained on magnetic tape. The machine can handle up to 90 entries a second, updating and comparing the updated entries with overdraft limits and stopped accounts. Finally, the computer turns out on five-channel paper tape a list of accounts that have been updated. This information is fed back to the branch concerned via the teletype link.

At 3:30 in the afternoon, after the close of normal banking operations, the branch sorts out the day's checks, prepares another list (and with it a punched tape), and sends this information to the central computer. The same procedure of sequencing and updating takes place. In addition, the computer prints out a balance list of the day's activity for each branch.

• **Fast statements**—To prepare periodic statements, the computer reads

For versatile Cylinder Control, specify Skinner 3- and 4-way Solenoid Valves

For small cylinders . . . Skinner V5 and V10 air and hydraulic valves. Stainless steel construction. Mount in any position; can be cleaned without removal from line. Pressure ratings to 1000 psi. Available normally open, normally closed, directional control, multi-directional, quick exhaust. Orifice sizes: 3/64" to 1/4".



For medium cylinders . . . Skinner 3 way A Series valves. A new line that can also be used to operate smaller cylinders calling for increased cycling speeds. Die-cast, zinc body; stainless steel internal parts; mount in any position. Available normally open, normally closed, directional control. Pressure to 125 psi; orifice size, 5/32".

Coming soon . . . for larger cylinders! A new-design, general purpose, high-flow industrial line of 3-way solenoid valves. These new valves will be available in orifice sizes of 3/8", 1/2" and 3/4" and will be offered normally open, normally closed, or directional control in standard and explosion-proof construction. Operating pressures: 5 to 150 psi.

For double-acting cylinders . . . Skinner 4-way V9 valves. Two 3-way valves in one housing offered normally closed-normally closed, normally open-normally open, and normally closed-normally open. Available with adjustable flow features for exceptional cylinder control. Orifices: 3/64" to 1/8". Pressure ratings to 200 psi.

Exhaustive lab tests assure that you can use any Skinner valve with confidence. Built to the highest UL standards, Skinner valves are completely tested and checked to provide the best product available. Skinner's testing standards meet or surpass those of the aircraft industry.

A complete line of 2-, 3- and 4-way solenoid valves. There's a Skinner valve for almost any flow application with a wide variety of media: air, oil, water, inert gases, hydraulic fluids, kerosene and gasoline. Orifice sizes range from 3/64" to 1". Pressure ratings range from vacuum to 3000 psi. Explosion-proof models are UL approved for Class 1, Group D and Class 2, Groups F and G.

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. . . full scale mechanization of British banks is still a long way off . . .

out the master magnetic tapes. Statement preparation is spread over a four week period to ease the load. All account information is stored on two fast, start/stop, one-inch magnetic tape decks. Each 2,400-ft reel of tape stores account information for three branches. Such information includes account number, name of client, interest rate, bank charges, and the balance of the account. When updating an account, the system insures nondestructive readout and record permanency by reading off one tape and writing the updated entries on a second tape.

Input checks are made on the teletype link and the computer. Control totals check the amounts received over the communication net, and check digits in the account numbers direct correct posting of the entries.

• **Central bank automation**—Mechanization of individual bank operation is one part of the bank mechanization program underway in Britain. Another aspect, probably lagging behind similar activity in the U. S., is automation of central check clearing houses. In London, three million checks pass through the 11 clearing banks each day. In 1956, the clearing houses set up an Electronics Advisory Committee to study the job of clearing. As a result of a three year study, the committee recommended standardization of check sizes, standardization of coding type face at 8 to the inch and limited in height to ⅛ in., and magnetic ink for encoding checks. Many of the recommendations parallel those proposed by the American Banking Association.

But full scale mechanization of central banking functions is still a long way off. English banks are waiting to see automatic feed sorters for selective sorting of checks in the clearing houses, readers for magnetic ink coding, and encoders for inserting the check amount on the check.

—Derek Barlow

•

Original Soviet patents and inventions, translated into English, are now available from Pergamon Press, Inc., in New York. Cost of each translated patent: \$5. Cost of an annual compendium of 2,000 pages: \$100. The book contains about 10,000 Russian patents.

Here's how one airframe and missile builder plans to take its control know-how and market it to industry and military and nonmilitary government agencies.

LEADERS AT LEAD:
M. C. Haddon, general manager, tries a button; Joseph M. Katz, head of the Ferrite Laboratory, turns a wheel; while R. C. Galbraith, assistant general manager, observes the action.

Lockheed's LEAD: A Start in Control

LOS ANGELES—
At Lockheed Aircraft Corporation last month, an active addition to the company was getting its feet wet in control waters while also probing the deeper end of the pool. The Lockheed Electronics and Avionics Division (LEAD) was unveiling its first products and was getting ready to tackle industrial markets that were brand new to the company.

It was no surprise last March when Lockheed officially established LEAD, for the company had made no secret of its interest in getting into the electronics and control field, particularly when the shift from aircraft to missiles drained a large share of dollars in prime contracts from the airframe builder's till to those of electronic companies. For a couple of years, Lockheed had tried to buy Hughes Aircraft Co., but the two were never able to get together. Finally, the big aircraft company decided to go it alone and launched LEAD.

• Planned for growth—Lockheed Board Chairman Robert E. Gross says, with LEAD, the company is preparing for the next 25 years, when electronics will be a major factor in defense programs and the civilian economy. For the next few years, growth will be the major goal. LEAD's new general manager, M. Carl Haddon, says smilingly, "Our intention is to make LEAD the biggest division in Lockheed."

To do this, Haddon expects eventually to sell 50 percent of his division's output to industrial users and nonmilitary government agencies.

As a starter, LEAD opened up temporary headquarters in a Lockheed-owned plant last March. Its plans and concept were blueprinted by Dr. Louis Ridenour who had been research director of the Lockheed Missiles and Space Div., but LEAD suffered a setback when Ridenour was stricken with a fatal heart attack in May.

The division drifted along with no general manager until July when Haddon, a 20-year veteran with Lockheed, was appointed to the post. Haddon is a vice president of the aircraft builder and has been both chief engineer and marketing director of the California Div., which builds commercial and military aircraft. He will implement the blueprint put together before Ridenour's death.

• A unique position – Right now LEAD is in a position which few new companies are likely to duplicate. It has 130,000 sq ft of plant—most of it vacant—which eventually will be

WHAT'S NEW

. . . on the industrial side, some areas look riper than others, like automatic inspection . . .

filled with manufacturing facilities. Next month, the division will break ground for administrative, research, and engineering headquarters on a 200-acre tract at Newport Beach, southwest of downtown Los Angeles. The engineering quarters are to be occupied by the fall of 1960.

LEAD now employs about 20 engineers. The division expects to increase this to 70 by the end of the year, but the growth will be closely geared to the areas in which LEAD finally decides to concentrate its efforts. Haddon points out that LEAD has not yet completely decided where it will fit best. "It is similar to being in a clover field," he says, "everything looks good but you have to decide on what part to concentrate."

At the start, LEAD will lean towards military applications, capitalizing on the $30 million worth of research and study in electronics which Lockheed performed at its other divisions last year. The company has a wealth of knowhow in aircraft control, missile control and instrumentation, and data handling.

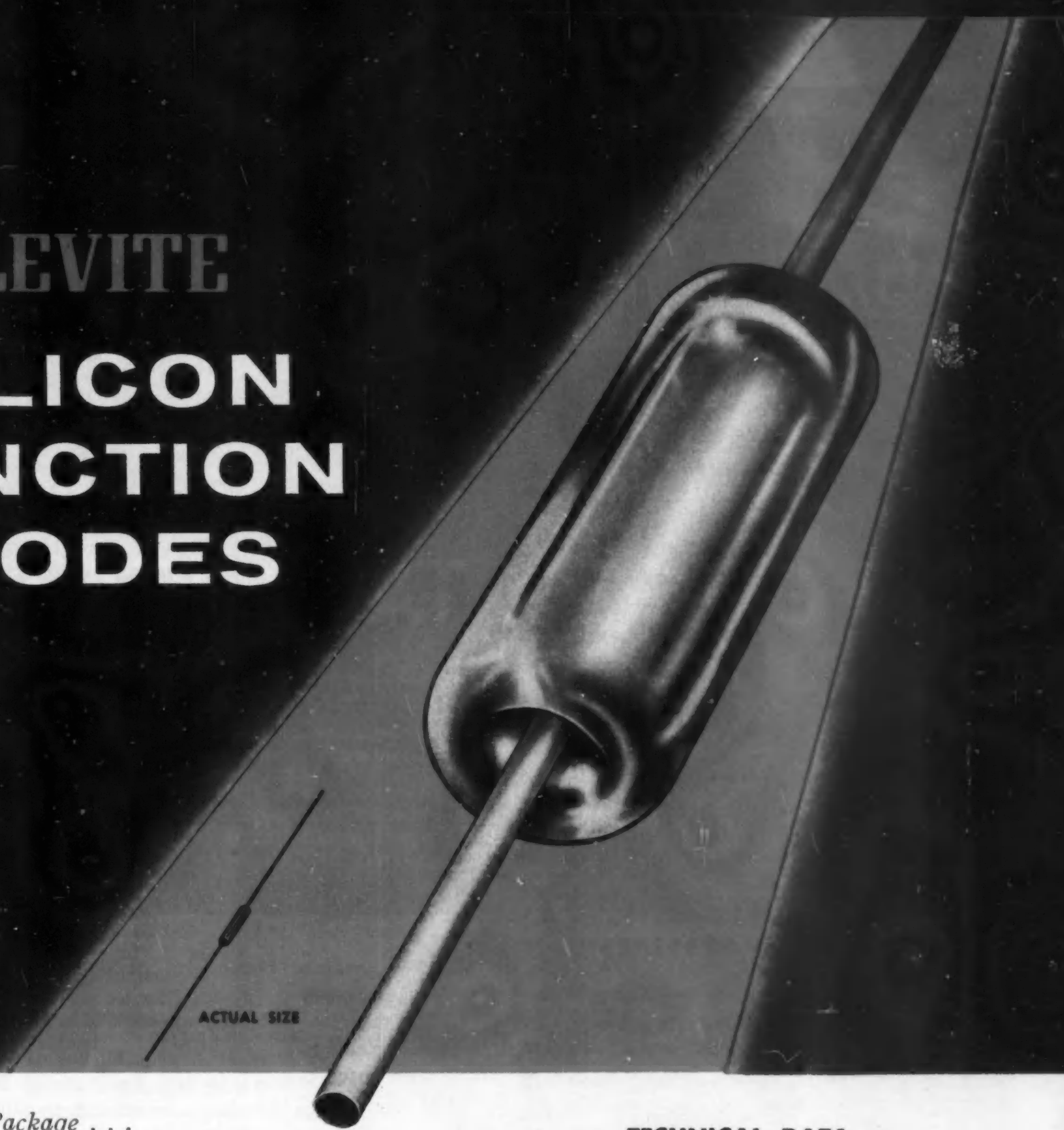
• **Two missile products**—LEAD's first two products are components in the data area, both for missile work. A high-power, wide-band FM transmitter is designed particularly for high speed PCM telemetry applications. And LEAD has designed a small television system capable of operating under extreme environmental conditions. In the plans for the near future are a small airborne magnetic tape recorder and a high speed printer. Haddon describes the division's other activities this way. "In the military end, we are bidding on systems, subsystems, and component projects. So far, most such bids have covered tape recorders, telemetering systems, and video telemetering systems."

LEAD has also bid on a programmer comparator for the B-70 and F-108 aircraft. The division's approach is such that the system will be standardized so it can be used on future aircraft too.

"On the industrial side," says Haddon, "we plan to work with customers to develop equipment they want. In our minds, some areas appear riper for electronic applications than others. For example, automatic inspection looks like a good one. The work being done by the Post Office Depart-

CLEVITE

SILICON JUNCTION DIODES



250 MW Package . . .
Fast Switching and JAN Types
Featuring . . .

- **MECHANICAL RELIABILITY — Rugged, hermetically sealed, subminiature packages. Designed to meet both military and commercial requirements.**
- **ELECTRICAL SUPERIORITY — Excellent high temperature operation . . . thermally stable . . . high forward conductance . . . efficient rectification.**
- **JAN TYPES—IN457, IN458 and IN459 conform to JAN Specifications**

For details, write for Bulletin B217A-1 B217A-2

TECHNICAL DATA

Type	Max. DC Inver. Oper. Voltage	Forward Current @ Specified Voltage	Max. Inverse Current @ 25°C	Max. Inverse Current @ 150°C	Test Volts
IN457	60 V	20 ma @ 1.0 V	0.025 μa	5.0 μa	60 V
1N458	125 V	7 ma @ 1.0 V	0.025 μa	5.0 μa	125 V
1N459	175 V	3 ma @ 1.0 V	0.025 μa	5.0 μa	175 V
1N662	90 V	10 ma @ 1.0 V	20 μa	100 μa (@ 100° C)	50 V
1N663	90 V	100 ma @ 1.0 V	5.0 μa	50 μa (@ 100° C)	75 V
1N778	100 V	10 ma @ 1.0 V	0.5 μa	30 μa (@ 125° C)	100 V
1N779	175 V	10 ma @ 1.0 V	0.5 μa	30 μa (@ 125° C)	175 V

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TRANSISTOR PRODUCTS
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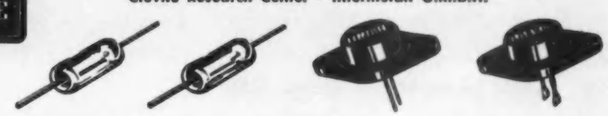


Silicon Junction Diodes **Germanium Diodes** **Power Transistors** **Solder Lug Power Transistors**

ment (see the Electronic Post Office, Page 28) and the Weather Bureau also offer attractive possibilities."

Lockheed's new division has proposed a major electronic system (whose nature is being kept a closely guarded company secret) with a nonmilitary government agency. The proposal calls for research and production.

Haddon expects that LEAD will eventually develop all its own products for both the military and the civilian market, although some of the initial products to be marketed will be developed by other Lockheed divisions.

• **Bigness helps**—Being a division of a big company has given LEAD some considerable advantages. For one thing, it will not be lacking financial backing for promising projects, whether in the research or development phase. LEAD will be able to exploit ideas which may take years to mature. In addition, LEAD's relationship with Lockheed will keep it in intimate contact with developments in the aircraft, missile, and space fields.

And association with Lockheed has given the new division a running start on personnel. Many of the top positions are being filled by veteran Lockheed technical people. For example, Steven J. Jatras, formerly assistant to the director of research at Lockheed's Missiles and Space Div. has been appointed director of marketing at LEAD. Dr. Samuel B. Batdorf, a physicist who has headed the technical team responsible for the U.S.'s communication satellites while on leave from Lockheed's Missiles Div., is LEAD's top research scientist. Other Lockheed transfers: Howard S. Hagen (Missiles) becomes industrial relations director; Russell C. Galbraith (California Div.) has been appointed assistant general manager.

Lockheed's considerable plans for the new division prompt general manager Haddon to say "We are going to establish trends in military and industrial electronics. We intend to do what our name says—LEAD!"

—Kemp Anderson
McGraw-Hill News

U.S. Users and Makers Continue Foreign Growth

U. S. control companies continued to expand overseas last month. Four control makers announced plans to build foreign factories and to set up foreign sales organizations; a machine

(*Continued on page* 184)

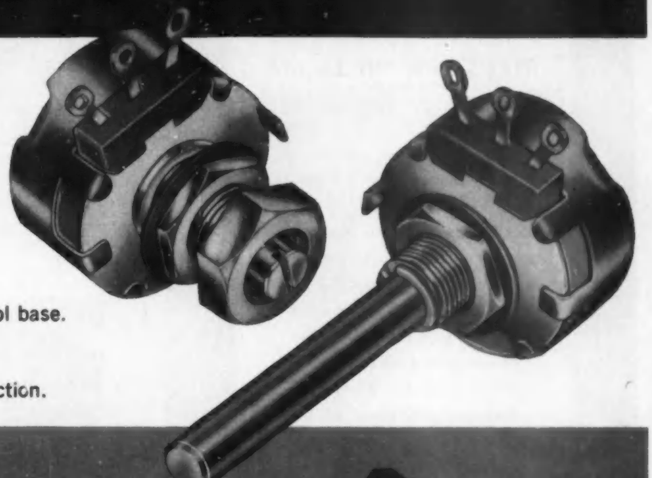
the extraordinary molded carbon potentiometer...

CLAROSTAT SERIES 53

Used and proved superior in tens of thousands of installations, the Clarostat Series 53 molded carbon potentiometer is now available in quantity schedules to meet any production requirement.

The extraordinary performance and reliability of the Series 53 result from a Clarostat-conceived design that eliminates all metal-to-metal movable contacts, reducing noise, wear, and backlash.

For any application requiring the inherent superiorities of the molded carbon potentiometer, check the extraordinary features of the Clarostat Series 53 before settling for the ordinary . . .



- **Pre-molded and pre-selected resistance element.**
- **One-piece carbon contact with simultaneous contact on resistance element and collector terminal.**
- **Zero backlash. Maximum stability.**
- **Gold-plated terminals for easiest soldering.**
- **Grease seal around shaft.**
- **Terminals molded in element and control base.**
- **Full 2-watt rating at 70°C.**
- **Available in completely encapsulated units for maximum environmental protection.**

SPECIFICATIONS

POWER RATING: 2-watts at 70°C
RESISTANCE RANGE: Linear—50 to 10 meg. Tapered—250 to 5 meg. (Right or left-hand)
INSULATION BREAKDOWN: Between terminals and ground for 1 minute, 1000 v.d.c.
SWITCHES: SPST, SPDT, DPST
TORQUE: 1 to 6 oz. in. Up to 20 oz. in. with jam nut bushing.
EFFECTIVE ROTATION: 312° ± 3°
CONSTRUCTION: Meeting requirements of MIL-R-94 where applicable.

direct line service

IMMEDIATE DELIVERY!

Phone your local Clarostat Industrial Distributor for popular, standard Series 53 or military style RV-4 units...for fast delivery from local stock.

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CLAROSTAT MFG. CO., INC.
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CIRCLE 55 ON READER SERVICE CARD

*ElectriK Tel-O-Set** control system—

the <u>only</u> true two-wire system

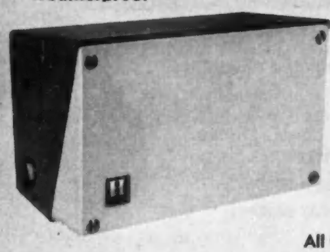
is safe, simple, economical to install

HERE'S HOW THE *ElectriK Tel-O-Set* SYSTEM WORKS

The basic system consists of a transmitter, receiver, controller and final control element. The transmitter measures the process variable, translates it into a standard 4-20 ma d-c signal, and transmits to the receiver through a pair of unshielded wires. The receiver indicates or records the signal in terms of the actual value of the process variable, compares it with the set point, and sends the difference to the controller as an error signal. The controller then converts this into a corrective 4-20 ma output to operate the control valve —again transmitting over a pair of unshielded wires.

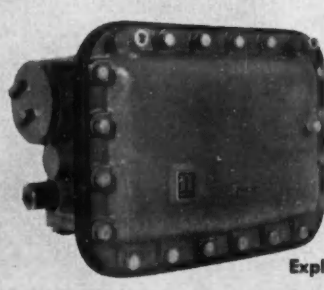
TRANSMITTERS

Weatherproof



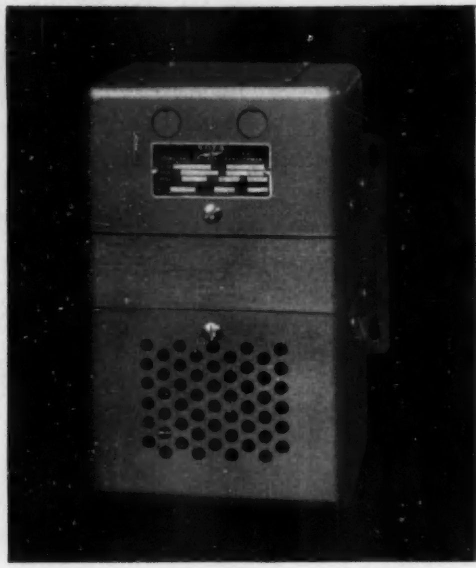
Relay rack

All transmitters are completely transistorized and have quick-connect electric plugs. All process and external electric connections to transmitters are isolated from the inside of the case, to permit installation without the need for instrument department supervision.



Explosion-proof

Sola reduces prices on ±1% static-



Sola Sinusoidal type Constant Voltage Transformers for universal application, now moderately priced

Housed unit with mounting plate typical of structures employed in 60va to 1kva ratings.

An important advance in the field of voltage regulation is the development of a new line of Sola Standard Constant Voltage Transformers with sinusoidal output. New design enables us to price them about the same as previous models not having sine-wave output. Now you can have the advantages of ±1% static-magnetic voltage regulation in new applications requiring harmonic-free input where previously the cost was a deterrent.

These new units provide output voltage regulation of ±1% for line voltage variations as great as ±15%. They regulate automatically and continuously. Fast response time averages 1.5 cycles or less. Output has less than 3% total rms harmonic content, and formulae based on sinusoidal wave shape may be used in designing related load circuitry.

Design and production innovations make these new units substantially smaller and lighter than previous models. They are relatively compact compared to other equipment for comparable ac voltage regulation. They are easy to select and order —the buyer merely selects the stock unit whose output capacity equals or exceeds the desired equipment input. Sola Standard Sinusoidal CV Transformers are available in nine stock output ratings from 60va to 7500va. Custom designs to meet specialized requirements are available in production quantities.

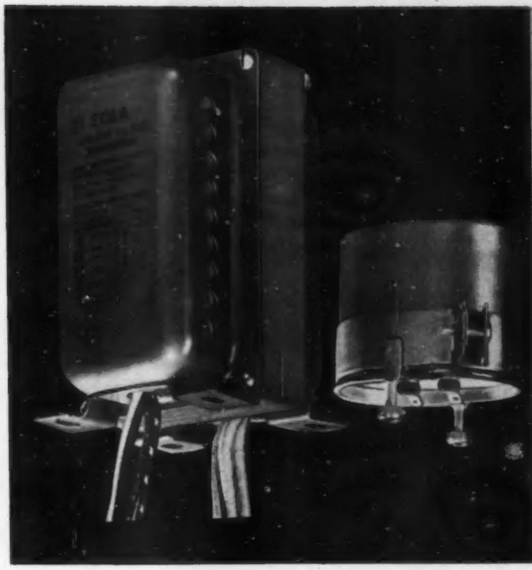
Write for full information . . .

With electrical control systems and components continuing to increase in number and complexity, and imposing more rigid reliability requirements, these new Sola Constant Voltage Transformers provide many advantages and virtually unlimited application. They are the result of over four years of development, design, and production engineering in the Sola laboratories and plant.

These developments mean superior voltage regulation, giving you a bonus in equipment reliability and performance at no increase in cost.

For full information, please write for technical literature on Sola Constant Voltage Transformers. We will mail it promptly, or if you wish, we will have a representative call on you.

magnetic voltage regulators



Sola Normal-Harmonic type Constant Voltage Transformers now specifically designed and priced for component use

End-bell unit with separate capacitor typical of structures engineered for component use.

Re-design of Sola "Normal-Harmonic" type static-magnetic voltage regulators has resulted in a significant reduction in their size and weight. Prices on many of these units have been reduced. Now it's possible for you to improve equipment performance by using them in many new fields at less cost than ever before. Re-design has in no way sacrificed the performance of these units—they provide all the outstanding benefits which have made them the standard of the industry for more than fifteen years.

Sola Normal-Harmonic type voltage regulators provide ±1% output voltage with line voltage variations as great as ±15%. This group has an average of 14% total rms harmonic content in its output voltages and is suited to equipment not extremely sensitive to voltage wave shape.

Sola Normal-Harmonic type voltage regulators are available in nineteen stock ratings from 15va to 10kva, including those mechanical designs specially engineered for use as built-in components. With many of the most popular ratings now reduced in price, these Sola Constant Voltage Transformers provide one of the most economical means of close voltage regulation in a broad range of applications.

Sola Manufactures: Constant Voltage Transformers, Regulated DC Power Supplies, Constant Wattage Mercury Lamp Transformers and Fluorescent Lamp Ballasts

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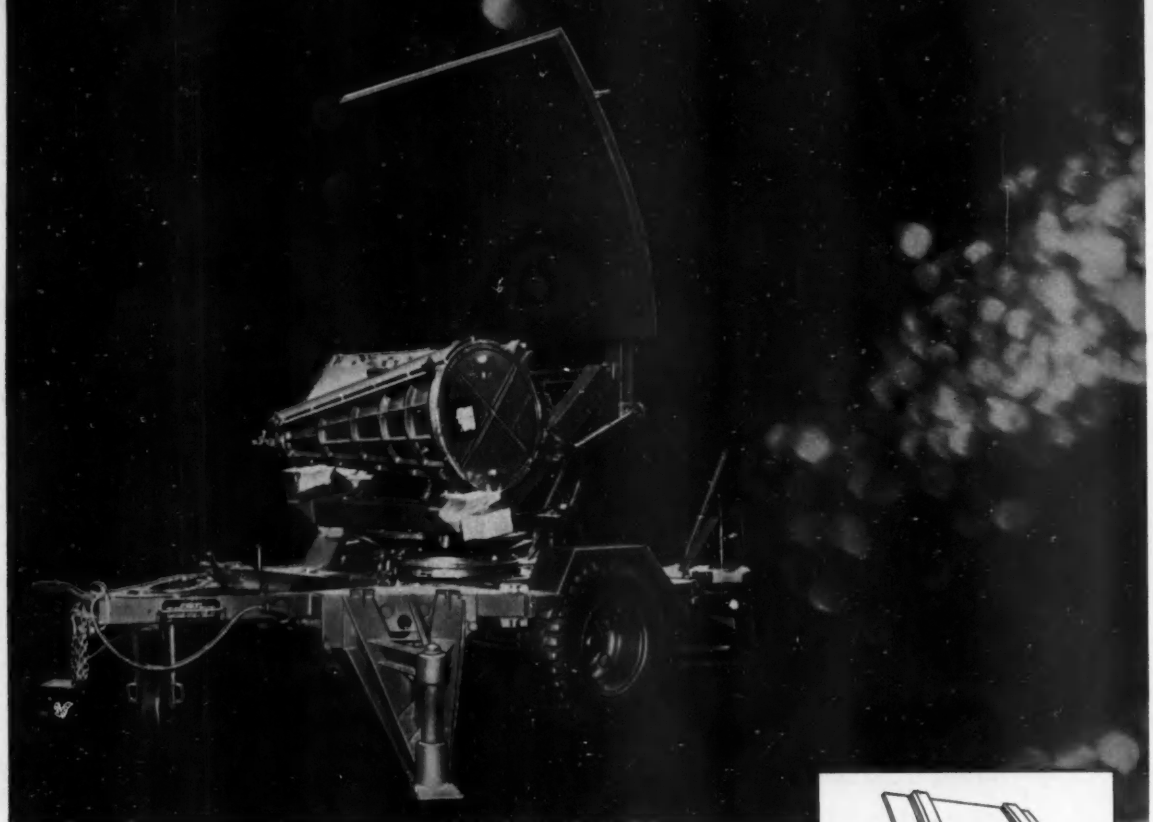
A DIVISION OF BPC BASIC PRODUCTS CORPORATION

SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois

Sales Offices in all principal cities

IN CANADA, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 18, Ontario

Diversified electromechanical systems capability



AiResearch Actuation Systems For Portable Radar represent a typical electromechanical systems application in ground support equipment. Two types of AiResearch actuation systems are now in production for the Army's mobile trailer-mounted ground radar unit. They consist of a manually operated antenna folding storage system and an electrically powered antenna elevation system.

Designed to operate under the most severe environmental conditions, this type of electromechanical system can operate on 60 cycle A.C., 400 cycle A.C., or 28 volt D.C. Other suggested applications include: *missile launchers, missile ground handling and support equipment, armored vehicle fire control and ballistic handling systems, and mobile communications equipment requiring servoed actuating systems.*

AiResearch leadership in the development and production of electromechanical equipment for aircraft, ground handling, ordnance and missile systems of all types also includes such recent examples as spoiler servo control systems, magnetron and Klystron tuning devices, and safe-arm mechanisms for missile igniting. We invite you to submit a problem statement of your electromechanical requirements.

U.S. Army Signal Corps ground portable radar unit operated with two AiResearch electromechanical actuation systems.

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

There's 1 source for
2 way
3 way
or 4 way MIDGET SOLENOID VALVES
Progressive designers, the men who lead the trend toward miniaturization, depend on ASCO as the one source for a full line of midget solenoid valves. The unexcelled quality and dependability that ASCO pioneered in the solenoid valve field is found, too, in today's midget solenoid valves. Only the size has been reduced.
For flow applications using air, gas, water, light oil, refrigerants and many other liquids, ASCO Midget Valves assure complete safety and truly exceptional performance.
ASCO Midget Solenoid Valves are available with standard, watertight or explosion-proof enclosures. Pipe sizes 1/8" and 1/4"; pressure range 0-1000 psi.
There's *one* source that solves virtually any solenoid valve problem – ASCO. Write today for complete data on ASCO Midget Solenoid Valves – or outline any of your requirements. We'll be pleased to assist you.
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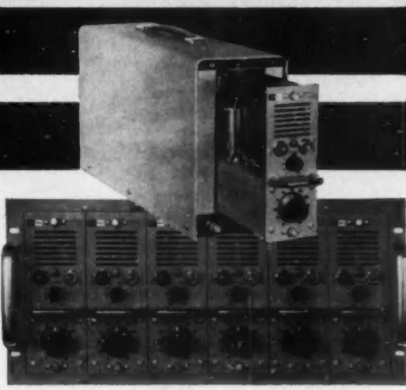
SHOWN 3/4 ACTUAL SIZE



111BF DC amplifiers in Model 195 single-amplifier cabinet and Model 190 six-amplifier 19" rack module.

HERE'S WHY THE KIN TEL 111BF DC AMPLIFIER IS THE BASIC COMPONENT FOR ACCURATE, DRIFT-FREE AMPLIFICATION OF MICROVOLT-LEVEL SIGNALS:

KIN TEL 111BF DC wideband amplifiers allow extremely accurate measurement of dynamic physical phenomena such as strain, temperature, vibration, pressure, flow, torque, and displacement. They greatly simplify the design of data measurement systems, offering more bandwidth and accuracy, reduced maintenance, and none of the capacitive balance problems inherent in AC carrier equipment. KIN TEL's proved chopper amplifier circuitry with multiple feedback loops assures operational stability and uniform frequency response regardless of load or gain changes. The capability of providing full bandwidth and full output into large capacitive loads, at high gain settings, places virtually no restrictions on the type of output device that can be driven and allows the use of longer output cable runs.

The 111BFO, an operational version of the 111BF, has an open-loop position instead of a zero-gain position. In this position the user may employ external networks to provide up to 100% resistive or capacitive feedback around the amplifier, allowing its use as an integrator, active filter, or to generate complex linear transfer functions.

Many thousands of KIN TEL DC amplifiers, with millions of cumulative hours of operation, are in day-to-day use. Virtually all major missiles programs–including ICBM–employ KIN TEL DC amplifiers in ground support instrumentation.

- **Less than 2μv drift for 100's of hours**
- **DC – 40kc bandwidth**
- **0.1% gain stability**
- **$\pm$45v, $\pm$40ma output**
- **100kΩ input, $<$ 1Ω output impedance**
- **20 to 2000 gain**
- **Full output into 1μf loads**
- **Integral power supply**

Prices:

111BF DC Amplifier	$625
111BFO DC Amplifier	$635
195 Single-amplifier Cabinet	$125
190 Six-amplifier 19" Rack Module	$295

Immediate delivery from stock on reasonable quantities.

(Note: Amplifiers must be operated in 190 Module or 195 Cabinet.)

KIN TEL manufactures electronic instruments for measurement and control, and closed circut TV. Representatives in all major cities. Write for detailed literature or demonstration.

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A DIVISION OF
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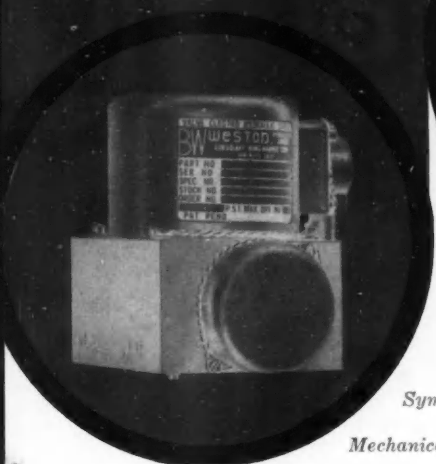
get all these features with the new WESTON ELECTRO-HYDRAULIC SERVO VALVE!



HIGH RELIABILITY

Symmetrical mechanical and hydraulic design

Mechanical feedback from second stage valve position

Dry coil torque motor

Large single filter for hydraulic amplifier

Dynamically balanced for resistance against vibration

Superior low temperature operation

The new lightweight Weston Electro-Hydraulic Servo Valve, developed after an extensive program of research and testing, combines all these outstanding features. The results are smooth, stable operation under a wide range of flow and temperature conditions, with more positive positioning accuracy and higher reliability even when used with contaminated fluids. Greater null stability is assured. For more information about the new Weston Electro-Hydraulic Servo Valve, write for Technical Report No. 101. Contact Weston Hydraulics, Limited, or any of the following offices.

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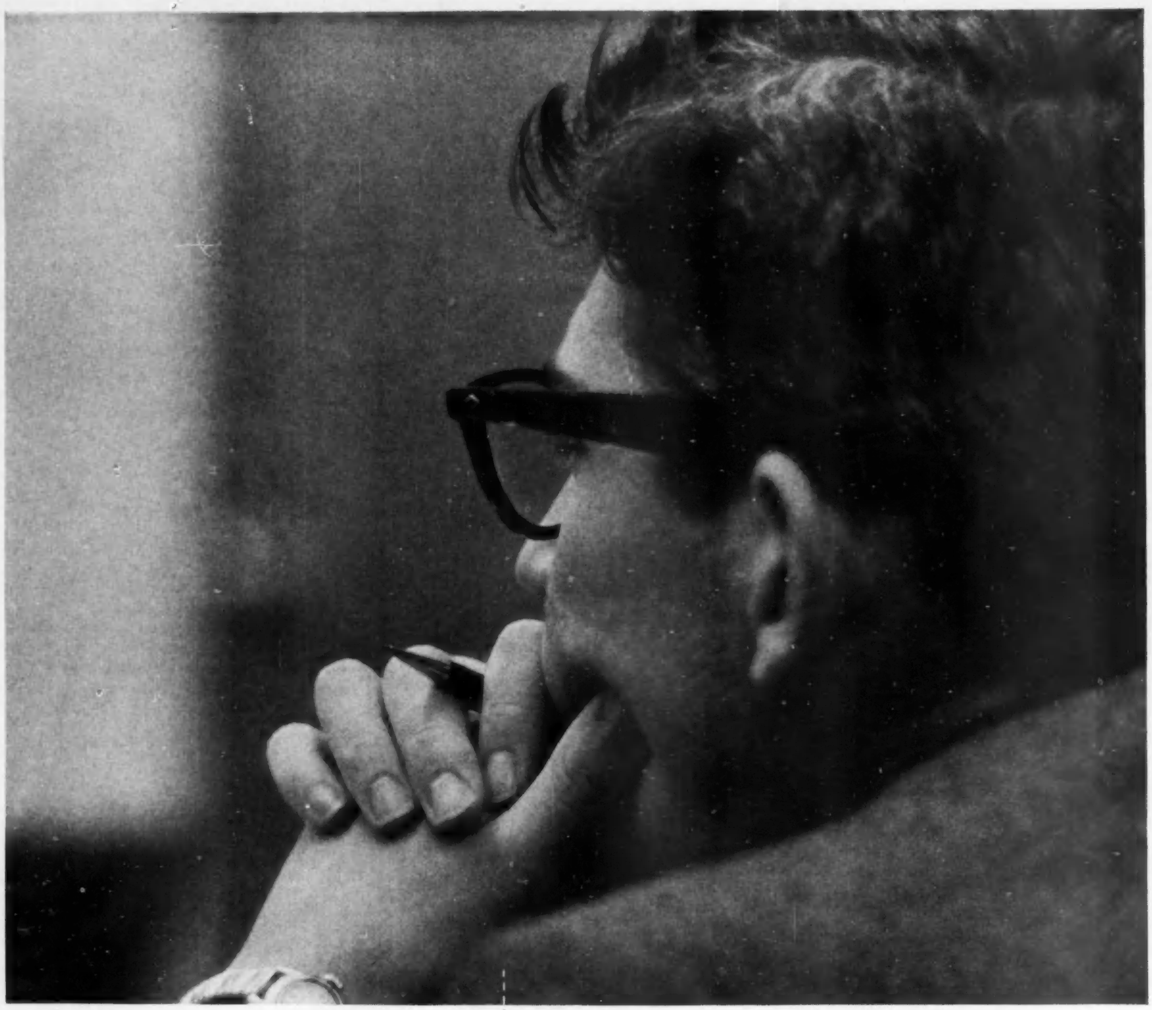

THE HUMAN FACTOR in today's technology

Scientists have long been preoccupied with the technological problems of Man and the Machine. The increasingly complex nature of advanced systems has created an urgent need to enhance man's contribution to effective systems performance. The complicated nature of this relationship requires the skills of psychologists, social scientists, mathematicians, and engineers.

At Ramo-Wooldridge, human engineering, personnel selection, individual and system training, display design, and communications are successfully integrated into systems design and development by the technique of large-scale simulation.

Simulated inputs enable scientists to observe a system as it operates in a controlled environment and make possible the collection of data on performance, training, human engineering, maintenance, and logistics and support. Scientists and engineers use this data to assure the design, production, and delivery of a unified system capable of high performance and reliability.

Expanding programs at Ramo-Wooldridge in the broad areas of electronic systems technology, computers, and data processing have created outstanding opportunities for scientists and engineers. *For further information concerning these opportunities write to* **Mr. D. L. Pyke.**

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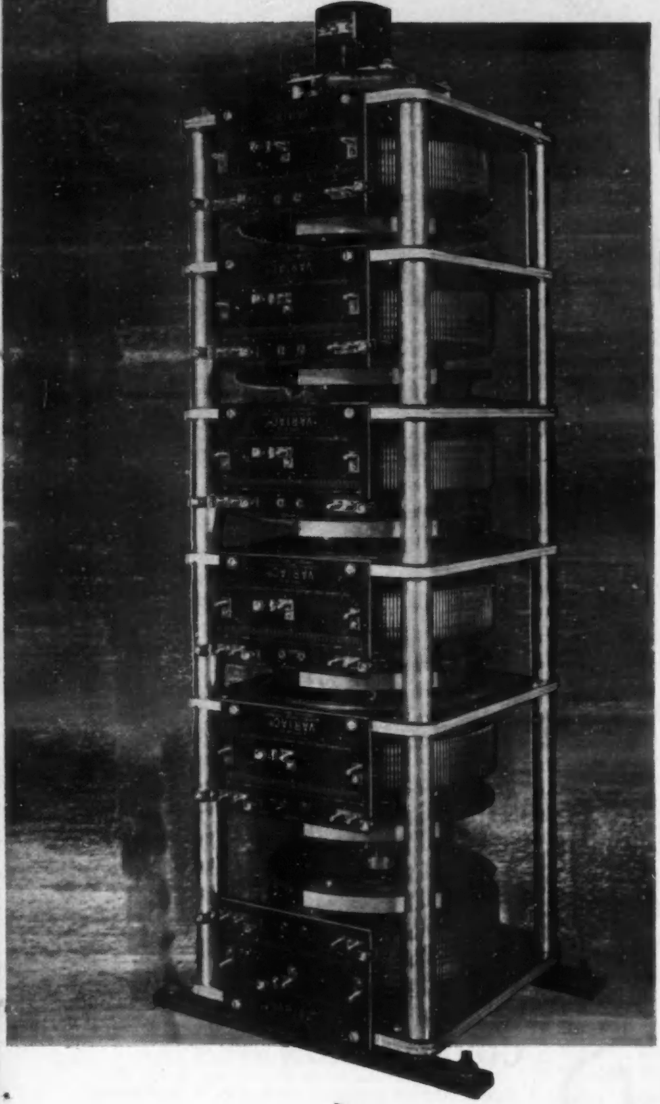
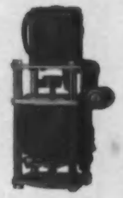
MOTOR DRIVES For BIG Variacs...



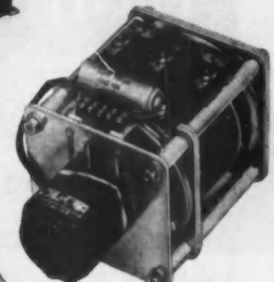
...and little Variacs



Type W2
2.4-amp . . .36 KVA

...and all sizes in between

Two-Gang W5 cased model . . .
5-amp per Variac . . .
1.8 KVA total



Type W10
10-amp . . . 1.5 KVA

Six-Gang W50
50-amp per Variac
34.5 KVA total

Three-Gang W20 . . .
20-amp per Variac . . .
9 KVA total

All Variac® auto transformers, single units and gangs, can be supplied with motor drive, either cased or uncased. Prices range from $99.50 for 2.4-amp Type W2 to $922 for six-gang 34.5-kva Type W50. Quantity discounts available.

ALL MOTOR-DRIVEN MODELS

★ are driven by a two-phase, servo-type gear-reduction motor, which may be operated from a 115v, 50-60-cycle line (necessary capacitor provided), or a servo amplifier.

★ can be supplied with electrical limit switches.

★ are equipped with ball bearings.

★ Traverse speeds of 2, 4, 8, 16, 32, 64, or 128 seconds are available in most models.

Write for complete information

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FIRST Quartz-Crystal Primary Frequency Standard 1926

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CIRCLE 69 ON READER SERVICE CARD

Edwin Felch, project director in charge of developing the Titan guidance system, holds the "voice" of the ICBM.

VOICE
OF A GUIDED MISSILE

This is a missile-borne transmitter. It is the "voice" of a missile in flight . . . part of a new radio-inertial guidance system developed by Bell Telephone Laboratories for the Ballistic Missile Division of the Air Force.

This versatile system helped deliver the nose cone of a Thor-Able test missile precisely to its South Atlantic target area—5000 miles from Cape Canaveral, Florida. So accurately was the nose cone placed that a waiting group of ships and planes retrieved it in a matter of hours. It was the first nose cone ever to be recovered after so long a flight.

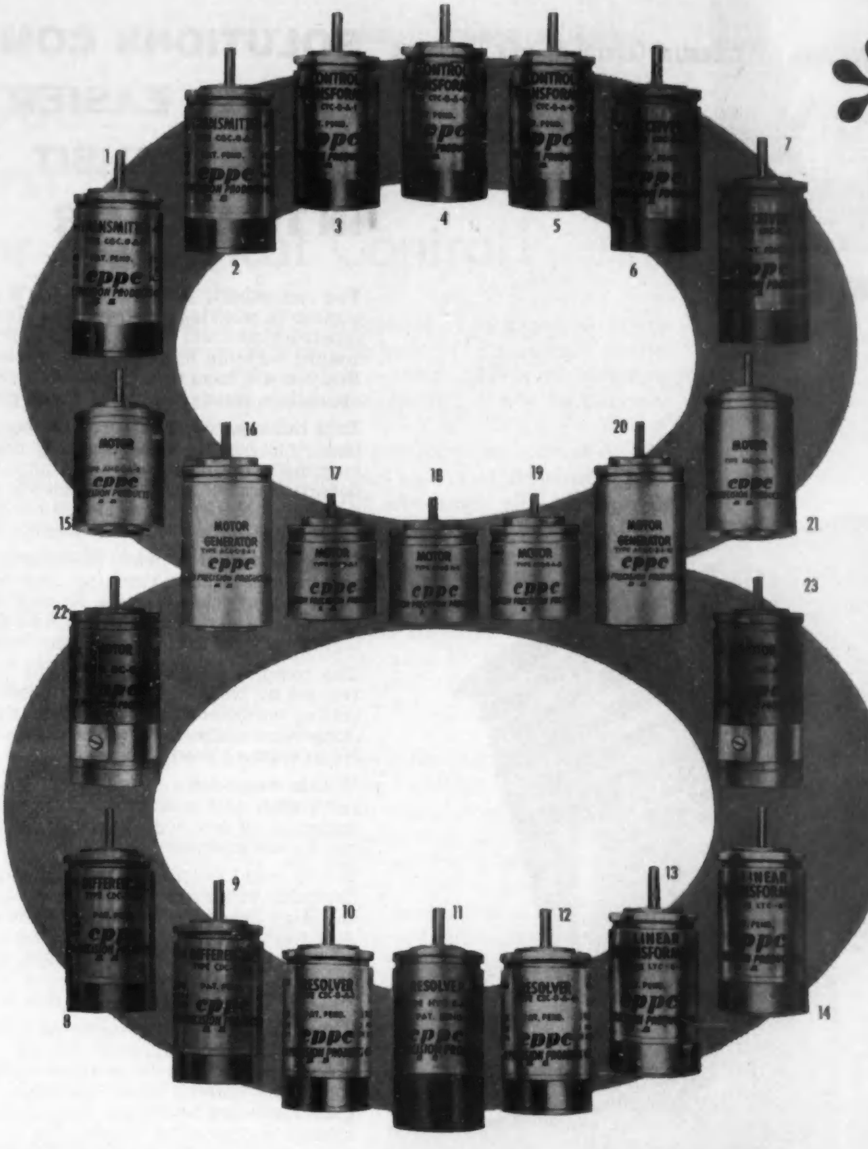
The command guidance system which made such accuracy possible combines precision tracking radar with a special Remington Rand Univac computer. Fed a steady stream of signals from the missile-borne transmitter, the ground-based equipment compares the missile's flight path with the preselected path. Corrective steering orders are computed and transmitted automatically to the missile. The ground station monitors the progress of the flight continuously and obtains immediate evaluation of mission success. And since the principal control equipment is kept on the ground, expendable hardware in the missile itself is minimized.

This radio-inertial guidance system is a product of the Bell Laboratories-Western Electric development-production team. It is in production at Western Electric for the first operational squadrons of the Titan intercontinental ballistic missile.

Bell Labs scientists and engineers developed the world's most versatile telephone network and much of our nation's radar. They have constantly pioneered in missile systems. From their storehouse of knowledge and experience comes this new achievement in missile guidance.

BELL TELEPHONE LABORATORIES

World center of communications research and development



1960 . . . First Big Year for Numerical Control!

After living for about 10 years in an atmosphere of invention, experimentation, and blue-sky predictions, the builders of numerical control systems will at last begin to see a payoff in 1960. This is the optimistic prediction made by 21 companies in reply to a survey by CONTROL ENGINEERING. The survey revealed that

- **control builders expect to sell more point-to-point systems in 1960 than the total produced in all the years up to and including 1959.**
- **the continuous-path market is still very much alive despite the pessimism that prevailed after completion of the big-machine building program subsidized by the Air Material Command.**

Behind the boom

Actually, insiders will not be startled by the results of this survey. For months the incentives for growth have appeared from many directions. First, of course, is the step-up in capital expenditures for industrial modernization that came with the end of the recent recession. Numerically controlled machines should be seen in greater numbers just because of this increased spending.

Far more important, however, are two other factors: (1) the greater familiarity of users with the benefits (and problems) that come with the addition of higher-level controls to conventional equipment and (2) the astounding productivity of hybrids, such as the tool changing units, that numerical controls have made possible. Cases in point:

- An East Coast maker of printed-circuit boards is anxiously awaiting receipt of his second tape-controlled multiple-spindle drilling machine. "The first is producing as much as 12 drill press operators."
- A big aircraft company reports that in less than two years it has acquired 15 numerically controlled machines, plans to buy "a substantial number" in 1960. And this same company is energetically looking for applications other than the usual milling machines, jig borers, and drill presses. Among the promising areas: welding, drafting, sheet-metal trimming, spinning, wind-tunnel model making, punching, testing, "and many more".
- A Houston, Texas, manufacturer of oilfield equipment conservatively admits that his first two machines have proved to be "very satisfactory. Will purchase more numerically controlled machines in 1960 if business is good."

Figures talk

CONTROL ENGINEERING's evaluation of the U. S. numerical control market is as follows:

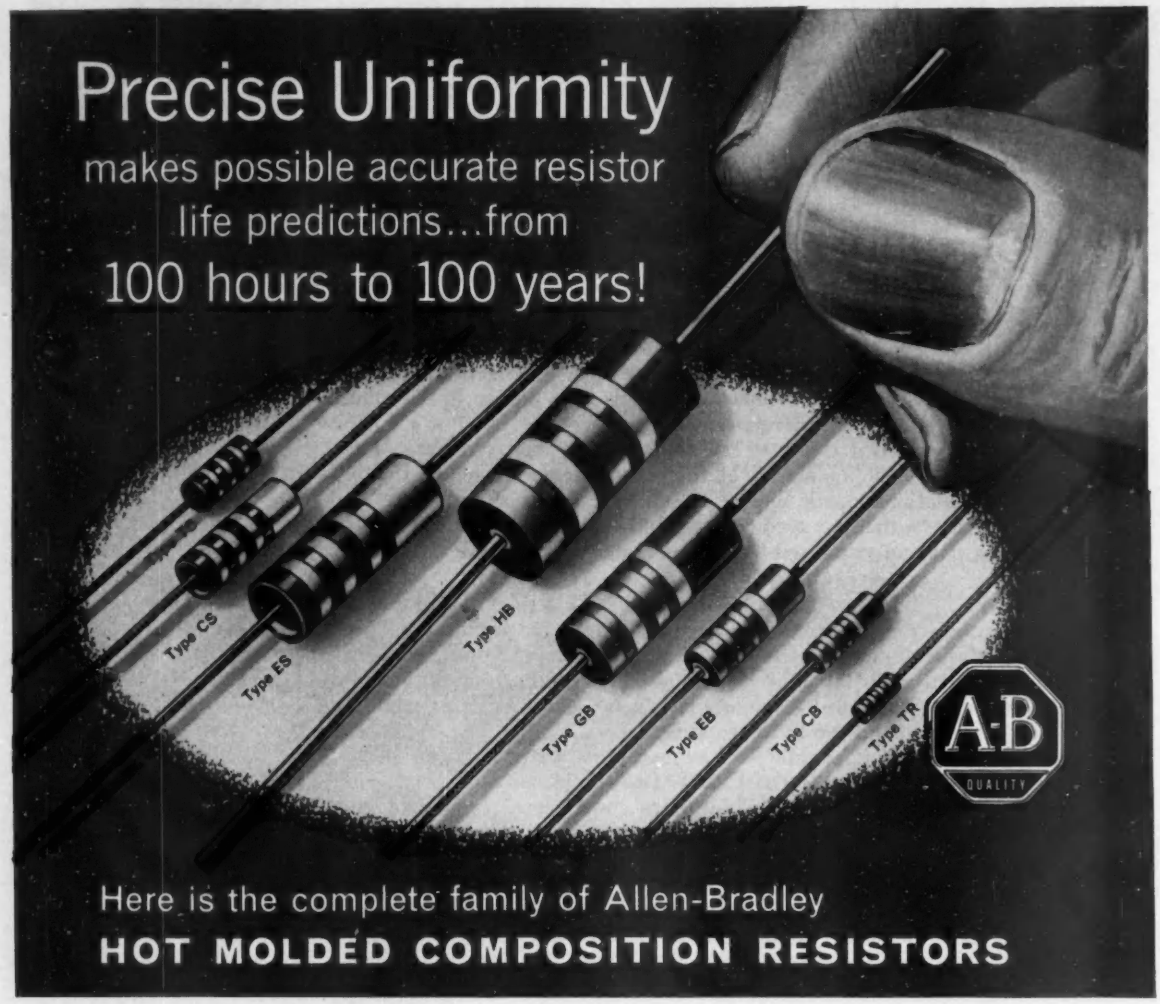
1—Total sales of point-to-point controls for all years up to and including 1959 is about $7.5 million for 635 systems.

2—Expected sales in the single year of 1960—$12 million for 985 systems.

3—Total sales of continuous-path controls for all years up to and including 1959 is about $7 million for 200 systems.

4—Expected sales for single year of 1960—about $4.5 million for 130 systems.

5—Grand total of 1960 sales for both point-to-point and continuous-path controls—$16.5 million for over 1,100 systems.

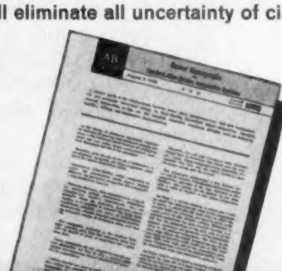


The exclusive hot molding process—developed and perfected by Allen-Bradley—produces resistors so uniform in their characteristics that, when combined with the analysis of test data accumulated over the years, it becomes possible to *accurately* predict the "life" of an Allen-Bradley resistor—from 100 hours to 100 years.

After years of carefully compiling test information obtained by Allen-Bradley Environmental Laboratories, as well as from many independent laboratories, power nomographs have been developed which show the relationship between power input, temperature rise, ambient temperature, life, and permanent resistance change for the standard Allen-Bradley composition resistors.

Inasmuch as catastrophic failure is unknown to occur with Allen-Bradley resistors, the design engineer can safely develop circuitry where predictable changes of characteristics are known and uniform. Furthermore, with Allen-Bradley resistors, changes due to humidity are temporary and cause no permanent damage to the resistors. Voltage characteristics and temperature characteristics are uniform and are known factors. No other composition resistors possess such uniformity of mechanical configuration, electrical characteristics, and life performance as do these A-B quality resistors.

The power nomographs published in the Allen-Bradley Technical Bulletin 5000E will eliminate all uncertainty of circuitry design in relationship to resistors—provided Allen-Bradley "quality" resistors are used. You will find this information very useful. Bulletin 5000E will be sent to you upon your request.



ALLEN-BRADLEY *Quality* ELECTRONIC COMPONENTS

Allen-Bradley Co., 210 W. Greenfield Ave., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

SOME MANUFACTURERS OF NUMERICAL CONTROL SYSTEMS

	Point-to-Point	Continuous Path
Automation Corp. of America, North Hollywood, Calif.		X
Bendix Aviation Corp., Controls Div., Detroit, Mich.	X	X
Carlton Controls Corp., Worcester, Mass.	X	
Cincinnati Milling Machine Co., Cincinnati, Ohio	X	X
CompuDyne Corp., Hatboro, Pa.	X	X
Data Systems Dept., Norden Div., United Aircraft Corp., Gardena, Calif.	X	
Electronic Control Systems Div., Stromberg-Carlson Co., Rochester, N. Y.	X	X
Electrosystems, Inc., Alhambra, Calif.	X	
Farrand Optical Co., Inc., Bronx, N. Y.	X	X
Giddings & Lewis Machine Tool Co., Fond du Lac, Wisc.	X	*
Hillyer Instrument Co., Cranford, N. J.	X	
Hughes Products Co., El Segundo, Calif.	X	
Jones & Lamson Machine Co., Springfield, Vt.	X	X
Machinery Electrification, Inc., Northboro, Mass.	X	
Micro-path Inc., Inglewood, Calif.	X	X
National Automatic Tool Co., Richmond, Ind.	X	
Pratt & Whitney Co., Inc., West Hartford, Conn.	X	*
Reliance Electric & Engineering Co., Cleveland, Ohio	X	
Specialty Control Div., General Electric Co., Waynesboro, Va.	X	X
Sperry Gyroscope Co. of Canada, Montreal, Can.	X	
Teller Co., Butler, Pa.	X	X
The Warner & Swasey Co., Control Instrument Div., New York, N. Y.	X	X

* Suppliers of contouring-type machines, but do not manufacture their own continuous-path control systems.

In addition to market statistics, the survey uncovered several side-lights of interest.

- Only two of the 21 respondents anticipate making a major redesign of their numerical control systems. Many reworked systems in 1959; others are standing pat.
- Milling, drilling, and boring operations still predominate as the applications for numerical controls. But here are some more novel uses: stretch forming, spin forming, jig grinding, spot welding, cut-off operations in web- or strip-type processes, model positioning, flight simulators, type setting and placement. And there's strong indication that the broad field of dimensional inspection is fast becoming a prime market.
- Reliance Electric and Engineering Co., big Cleveland builder of motors, controls, and drives, has developed a point-to-point system.
- One builder, who has been using and designing numerically controlled equipment since before the 1955 machine tool show, sold only 12 tape machines prior to 1959. With the better business climate and a new (and highly reliable) control, he equalled that figure in 1959 alone—expects to ship 30 numerically controlled machine tools in 1960.
- Sixteen control builders expect to sell 20 or more point-to-point systems during 1960. And six of these are gearing up to make 50 or more sets.
- One builder slashed a lot of objections to continuous path systems by the simple expedient of designing a relatively low cost control. He anticipates a spectacular sales performance next year: selling 60 continuous systems.

General Electric Semiconductor News

Prices cut another 20% on

Mass production of SCR's is now a reality. The experience, skill and manufacturing knowhow of General Electric's SCR production line is your assurance of dependable quality-controlled SCR's—an assurance unmatched by any other manufacturer.

WHAT THE SCR DOES

The SCR is a miniature semiconductor device that blocks positive forward voltage in its "off" or nonconducting state. However, by applying a small signal to the gate terminal it switches rapidly to a conducting state and acts like a single junction silicon rectifier. It is completely static, arcless and fast. It is almost 100% efficient. It contains no mechanisms subject to wear. As a result, the SCR can switch and control power either faster, more safely, less expensively or more reliably than the many devices it replaces: circuit breaker, relay, thyratron, magnetic amplifier, rotating amplifier and many others. Among the many hundreds of circuit designs are these:

Superior d-c motor operation from an a-c source. Eliminates motor generator sets, tubes or magnetic amplifiers to provide controlled d-c. Replaces mechanical speed and direction changers.

Superior a-c generation from a variable d-c source. First really practical method of using static inverters with ratings of several kilowatts.

Simpler conversion to high frequency. SCR converters are small and efficient. Extends use of high frequency power where desirable, as in fluorescent lighting systems.

Pulse modulators. Compact, yet rugged replacement for hydrogen thyratrons in radar and beacon modulators.

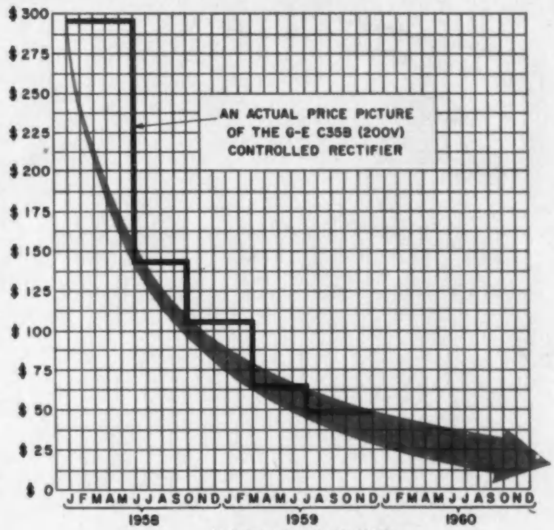
D-c regulation. Control large blocks of voltage with small losses by pulse width modulation. Eliminate bulky rheostats and adjustable d-c generators.

Other applications: Battery charging regulator, transient voltage protection, dynamic braking, constant current supply, static switching, regulated power supply, d-c to d-c conversion, temperature control.

silicon controlled rectifier

First test data revealed, new circuits developed, customer designs move into manufacturing stage

Prices again have been reduced an average of twenty percent on General Electric's Silicon Controlled Rectifier, providing greater values to users. These new prices have been made possible through expanding production and lower manufacturing costs.



GENERAL ELECTRIC
CONTROLLED RECTIFIER PRICE TREND

TESTS AND FIELD REPORTS PROVE RELIABILITY

Reliability of General Electric SCR's has been steadily improved over two years of manufacturing experience. Typical test results point to the reliability achieved to date.

- 98% survival after 1000 hours of storage at 125°.
- 97% survival after 1000 hours of operation at maximum ratings at 125°C.
- No thermal fatigue failures after 30,000 cycles from 20°C to 135°C and return.
- Less than one percent failures experienced by customers (many of which were traced to misapplication).

SCR NOW BEING USED BY MANY COMPANIES

The evaluation stage is passing rapidly into the application stage. Many products incorporating the SCR are being marketed, for the applications are proved, circuits refined and quantity production is a reality. These are just a few of the many cases where an SCR is now doing a job more efficiently, less expensively, faster or more reliably than previous designs:

- Power supplies incorporating transient voltage protection (for computers).
- Radar modulator.
- Static switch to replace mechanical relay for aircraft.
- Three phase inverter.
- Stage lighting lamp dimming.
- Regulated power supply.
- Battery charging regulator.
- Constant current supply for a magnetic yoke.

SEND FOR DESIGN INFORMATION

Detailed application notes and article reprints are available for the guidance of designers. Your General Electric Semiconductor Sales Representative will be pleased to provide you with complete details. Or write to Section S16109, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York. Many local G-E Semiconductor Distributors also stock General Electric SCR units for fast delivery at factory-low prices.

MAXIMUM ALLOWABLE RATINGS (Resistive or Inductive Load)

	C35U	C35F	C35A	C35G	C35B	C35H	C35C	C35D
Continuous Peak Inverse Voltage (PIV)	25	50	100	150	200	250	300	400 volts
Transient Peak Inverse Voltage (Non-Recurrent<5 millisec.)	35	75	150	225	300	350	400	500 volts
RMS Voltage (V_{RMS}), Sinusoidal	17.5	35	70	105	140	175	210	280 volts
Average Forward Current (I_F)	Up to 16 amperes							
Peak One Cycle Surge Current (I_{surge})	150 amperes							
Peak Gate Power	5 watts							
Average Gate Power	0.5 watts							
Peak Gate Current (I_G)	2 amperes							
Peak Gate Voltage (V_G) (forward)	10 volts							
Storage Temperature	−65°C to +150°C							
Operating Temperature	−65°C to +125°C							

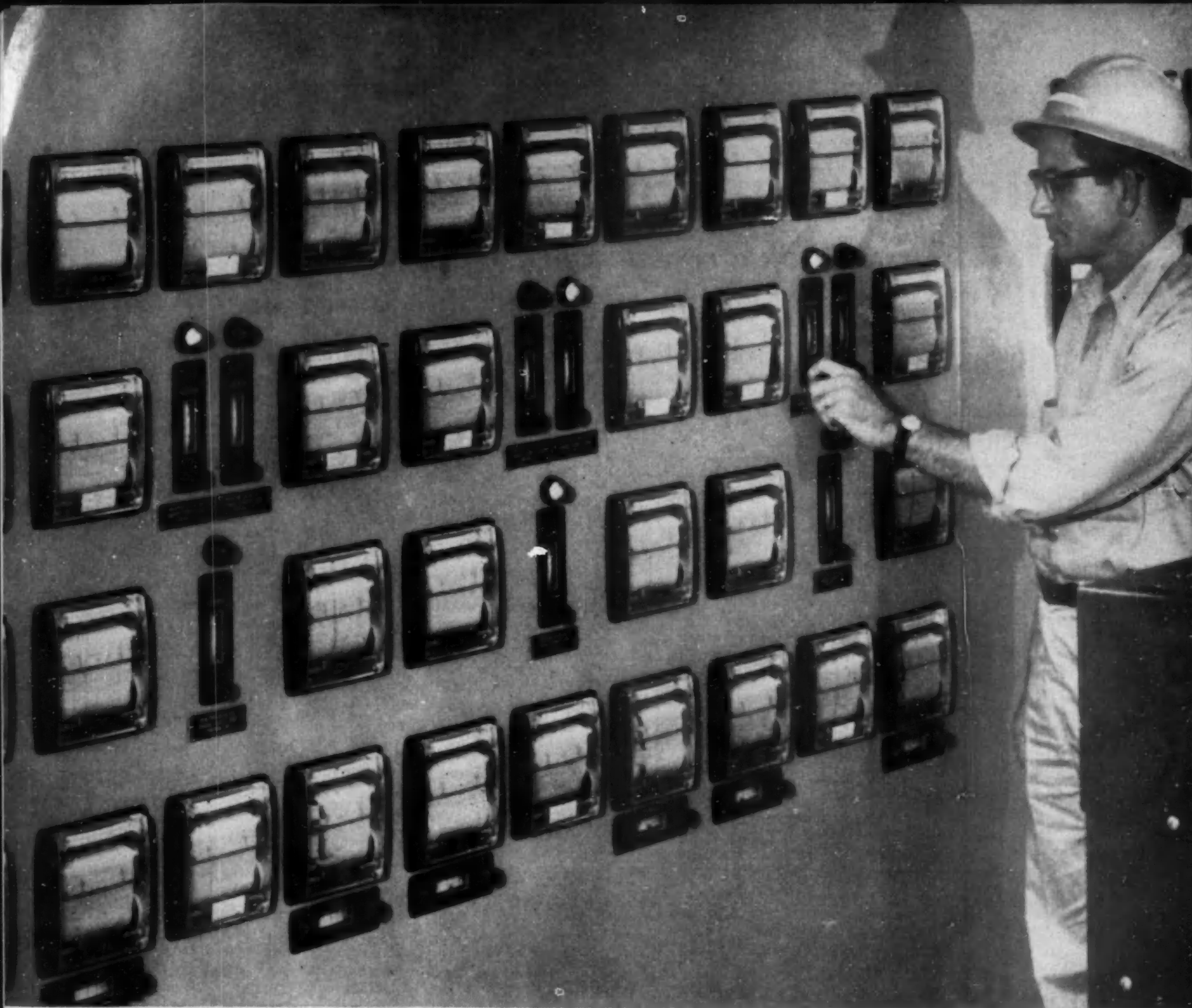
CHARACTERISTICS (At Maximum Ratings)	C35U	C35F	C35A	C35G	C35B	C35H	C35C	C35D
Minimum Forward Breakover Voltage (V_{BO})	25	50	100	150	200	250	300	400 volts
Maximum Reverse (I_R) or Forward (I_S) Leakage Current (Full Cycle Average)	6.5	6.5	6.5	6.5	6.0	5.5	5.0	4.0 ma
Maximum Forward Voltage ($V_{F\ AVG}$)	0.86 volts (Full Cycle Average)							
Maximum Gate Current To Fire (I_{GF})	25 ma							
Maximum Gate Voltage To Fire (V_{GF})	3 volts							
Typical Gate Current To Fire (I_{GF})	10 ma at +1.5 volts (Gate to Cathode Voltage)							

C-35 Series—lower cost series with ratings similar to above, but for use up to 100°C maximum, with forward current ratings up to 10 amperes.
ZJ-50 Series—a high-current series now in development, and available on a prototype-sample basis.

GENERAL ELECTRIC

Semiconductor Products Department

CIRCLE 79 ON READER SERVICE CARD



Foxboro Consotrol control panel at W. R. Grace & Co. polyethylene plant in Baton Rouge, Louisiana.

Foxboro Consotrols* help put 50 million pound

"Perfect instrument performance on start-up," reports W. R. Grace & Co.'s

50 million pounds of GREX — W. R. Grace & Co.'s new high strength plastic resin — that's the capacity of their new Polymer Chemicals Division plant in Baton Rouge, La. Instrumentation for the 30 acre, multi-million dollar facility was supplied by The Foxboro Company.

"Our main Foxboro panel was a big help in getting this temperature-controlled process off to a successful start," reports instrument supervisor Al Farris. "Over 95% of the variables on the panel are controlled — many of the key ones are part of cascade control systems. Instrument performance on start-up was perfect."

Grace instrument men like their Foxboro pneumatic Consotrols for other reasons as well: The M/54 Recorder's 4-inch vertical-travel chart . . . the drawer-type pull-out feature of Consotrols . . . the fact that in 18 months of operation not a single Consotrol has needed re-calibration.

Foxboro Consotrol instrumentation includes con-

*Reg. U.S. Pat. Off.

CIRCLE 80 ON READER SERVICE CARD

30-acre W. R. Grace & Co. Polymer Chemicals Division plant has 50 million pound annual capacity. First product — new high strength plastic resin tradenamed GREX.

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In high speed circuits, the switching types provide the lowest saturation resistance at high junction temperatures . . . permitting up to 5 mc pulse rates using saturated configurations and up to 30 mc pulse rates with non-saturating techniques.

The excellent high frequency response of the amplifier types permits the practical design of communications systems at frequencies up to 60 mc.

For complete data and application information, write Dept. CE-1059.

*Trademark Philco Corp. for Surface Alloy Transistor.
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CIRCLE 82 ON READER SERVICE CARD

Control
ENGINEERING
OCTOBER 1959

As Others See You

Have you ever considered the impressions that business managers, labor unionists, and the general public have formed of the effects of your measurement and control applications? You ought to, for if their impressions are unrealistic, your technically sound systems for improvement and modernization may be rejected—by the prejudice, fear, and lack of accurate perspective that spring from misinformation. You may say that you're a down-to-earth engineer, not a good-will ambassador. Your job is to solve the technical phases of control problems; the economic and social phases are someone else's job. Yet there's ample evidence that lack of general understanding of the true effects of measurement and control hinders applications.

Take the irrational fear of the hazards of radioactive gages that are used to measure density, thickness, basic weight, and level. The strongest unshielded field of these industrial gages is about 100 milli-roentgens per hour. A man would have to be exposed to this field for a full day to receive a dose equivalent to what he would receive if he had his chest x-rayed. Wage earners would not hold back from having the X-rays, but they have filed a grievance and demanded extra pay for "hazardous duty" when a radioactive gage with a field of only 3 milli-roentgens per hour was to be installed in their plant. Under this threat of labor trouble, the plant manager refused the installation. Its economic benefits, proved by extensive tests, never materialized.

Or take the general failure to impartially weigh all of the factors that ought to go into the formula for determining the productivity of machinery and operations. The factors are employment costs, material costs, capital costs, and management costs. Where a lot of manual operations are involved, the response of employment costs to applications of instrumentation and control is naturally sharper than the responses of the other factors. But in the processing industries and in the dispute-torn basic steel industry, the response of material costs predominates. Without a thorough exploration of which factor responds most actively, a general impression forms that instrumentation and control always cuts employment. To combat this simple and often false impression, you must dig out the facts that will fight prejudice with reason.

Present the facts impartially, but take them out of your technical vernacular and put them into the language of the people who surround you in business and society. Keep alive the creative gleam of the control field, but do everything you can to help others see in accurate perspective the results of your work. You owe it to them, and to yourself.

W. E. Vannah

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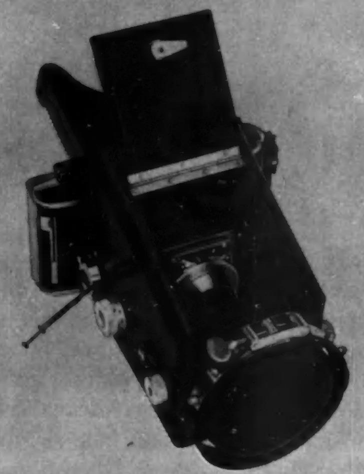

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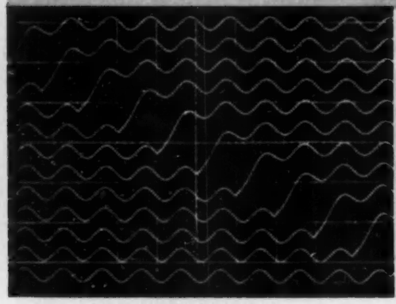
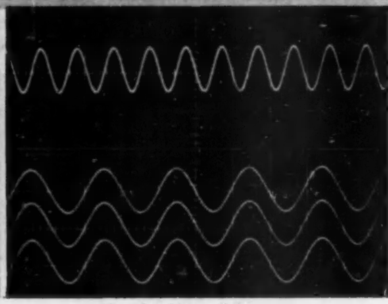
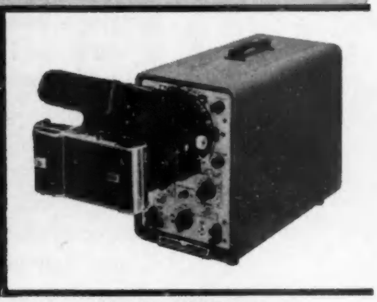


Up to 11 equally spaced exposures available



Two 4 x 10 cm field exposures. No overlapping



New -hp- 196A Camera on -hp- 120A Oscilloscope

The new hp 196A Oscilloscope Camera is the most convenient means yet devised for recording oscilloscope traces. Operation is extremely simple and swift; loss of film from light leakage is eliminated; mounting and unmounting takes just seconds; the entire unit is light weight, rugged, compact, yet a precision instrument in every respect.

Check the specifications below, and ask your hp representative for demonstration on your oscilloscope.

Object/Image Ratio:	1 to 0.9. (Adjustable to 1:1 ratio)	**Film:**	Polaroid ® Land types 42, 44, 46, 46-L.
Lens:	Wollensak 3" (75 mm) f/1.9 Oscillo-Raptar	**Size:**	13½" long, 9¼" high, 10" wide Weight 9 lbs.
Shutter:	Alphax #3. Time, Bulb, 1/100, 1/50, 1/25, 1/10, 1/5, 1/2, 1 second	**Accessories Available:**	Carrying case, Tektronix adapter
Print Size:	2-7/8" x 3-13/16"	**Price:**	$425.00

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hp WORLD LEADER IN PRECISION TEST INSTRUMENTATION

Dr. Draper's Floating Gyros Zero-in Thor on Target

FIG. 1. Thor rockets off the launching pad at Cape Canaveral under autopilot control, its inertial guidance system monitoring trajectory and ready to take over when initial flight is completed.

DONALD B. MacDONALD
McGraw-Hill News

Achiever, guidance in the Air Force's Thor intermediate range ballistic missile, is a self-contained inertial system that maintains a stable reference platform with floated gyros. During firing, the system operates for less than a minute, but it's a critical time: Achiever's performance determines whether the Thor hits the target or not.

In the 65-ft Thor intermediate range ballistic missile, the self-contained inertial guidance system sits just below the warhead, occuping only a fraction of the missile's 8-ft diameter. This critical electromechanical package—called Achiever by its designer and builder, the AC Spark Plug Div. of General Motors—primarily determines how close Thor comes to its target after its flight of 1,500 miles. Its accuracy is attributed to the floated gyros, originally designed by MIT's Dr. Charles Stark Draper, that maintain a stable reference platform independent of the earth, and measure acceleration after launching.

To appreciate the complexity of Achiever's job, you first have to understand something of the tactics of the ballistic missile. Military men loosely compare a ballistic missile to an artillery shell because both are guided only during the powered portion of flight. For Thor this is about 15 percent of total flight time. The artillery counterpart is the short period in which the projectile is in the gun barrel, where it is powered by expanding gases and directed by the barrel's azimuth and elevation.

After leaving the gun barrel, the artillery shell follows a trajectory affected only by air resistance and gravity. Thor follows a more involved trajectory which can be divided into three parts (Figure 2): an initial flight that lasts less than two minutes, an inertially-guided flight lasting less than one minute, and free fall, during which the missile covers most of its 1,500-mile range.

During the first stage of flight, a preprogrammed autopilot guides the missile. The autopilot is oriented entirely to missile attitude (the angle the centerline of the missile makes with a line passing through the center of the earth); it cannot react to other factors—internal or external—and it cannot recalculate in case of error. At the end of its performance, the autopilot maintains a constant attitude, for better or for worse, then hands guidance over to Achiever.

The inertial guidance system relates missile accelerations, target-launch point geometry, and free-fall influences such as gravitational force and the earth's rotation. It also has to assimilate and correct for any error incurred during the initial flight when the missile is guided by preset programming.

Right from launch, Achiever continually relates missile position to target position by sensing accelerations and by an implicit reference to time. And until Achiever actually takes over control, an air-borne computer constantly recalculates trajectory to compensate for external effects and environment.

Once in control, the guidance system has four separate functions: 1) to hone the aim originally provided by the autopilot; 2) to time the point of main engine cutoff; 3) to govern the timing and action during the brief period when two vernier engines are providing final attitude; and 4) to trigger warhead

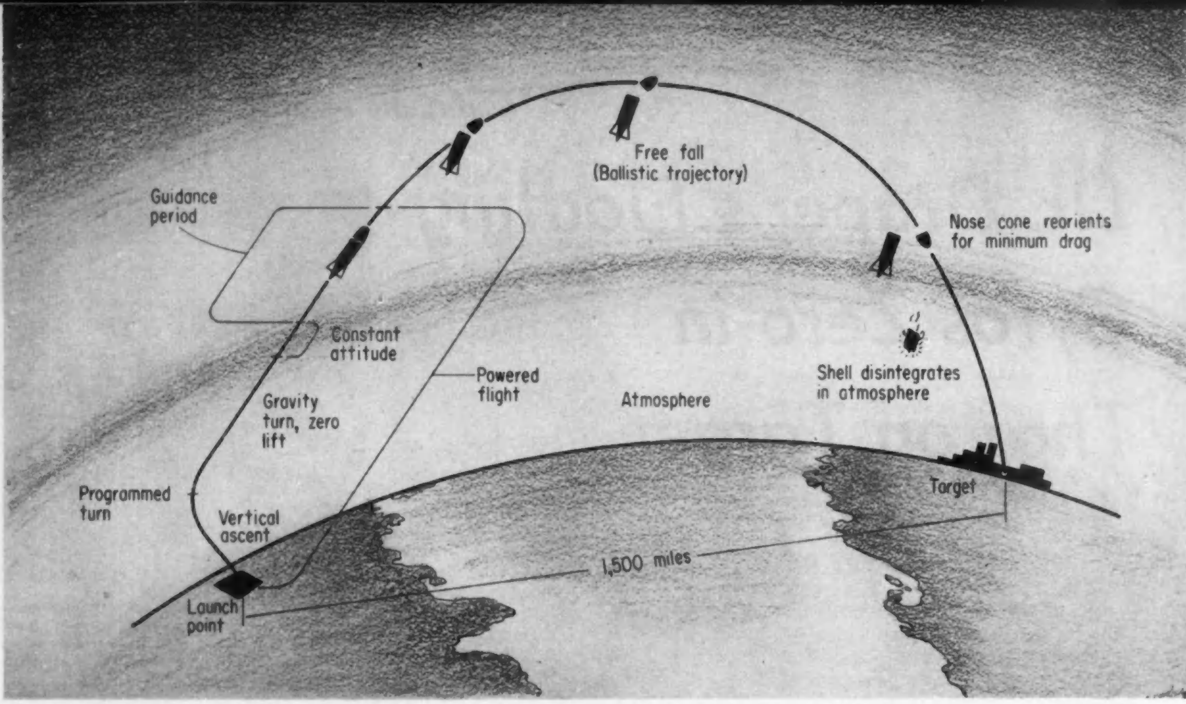


FIG. 2. Theoretical flight plan of Thor shows the three main parts of the trajectory: initial flight, inertial-guided flight, and free fall (power portion exaggerated).

separation at the proper instant in the mission.

The system in detail

The electromechanical package designed to do all these things can be divided into: power, measurement, computer, and ground support subsystems, Figure 3. The power subsystem runs the measurement and computer subsystems on usable energy converted from the electrical power of the battery and inverter.

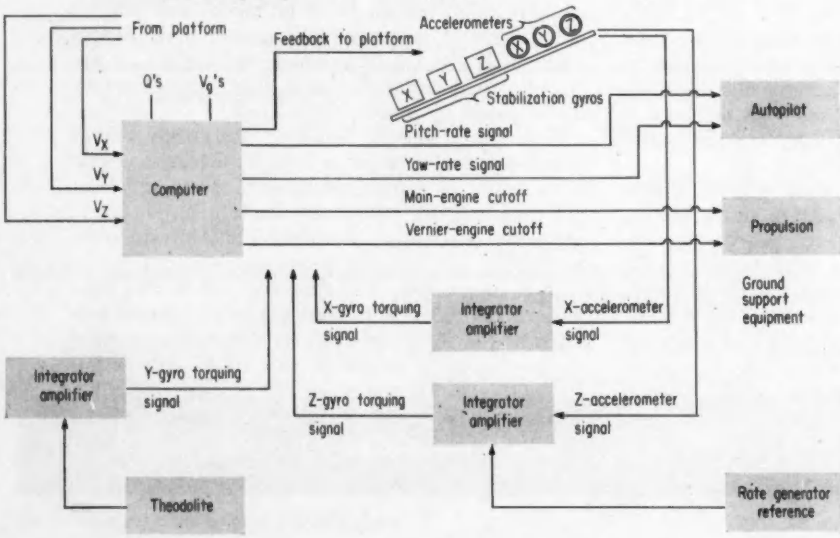
The measurement subsystem provides a set of stable measurement-reference coordinate axes and produces acceleration measurement signals. It contains servo stabilization loops to fix the platform relative to space during powered flight, and accelerometers to supply velocity data to the computer.

The computer, in turn, combines these signals with information preset on the ground to steer the missile and determine the exact cutoff points of the main and vernier rocket engines.

In the power subsystem are two primary supplies, 27-volt dc and three-phase, 115-volt, 400-cps ac. A few minutes before launch the source for both is shifted to batteries within the missile. Dc power actuates all relays and drives the inverter, which is controlled by phase synchronization (using an independent crystal supply as a reference). Ac is used in 6.3-volt form for tube filament supply and also to energize the B-plus power supply which produces the required high dc voltage for the system amplifiers. Certain critical circuits, such as the V_g potentiometer and gyro compensation, receive 7-volt, 400-cps, amplitude-regulated power.

The measurement subsystem is probably the most critical part of the guidance package and is responsible for its generic classification as an inertial system. It provides both the reference platform for acceleration

FIG. 3. Block diagram of Achiever. Section in upper half of diagram is in package carried under the warhead.



Behind the Thor Guidance System

The Achiever inertial guidance system descends almost directly from the pioneering work done by MIT's Dr. Charles Stark Draper on Project Spire 10 years ago. Spire was a self-contained navigation system intended for manned aircraft. It was freed from reference to the earth because it used a gyro-stabilized platform.

To obtain the degree of accuracy required for precision bombing, Draper developed the floated, integrating, single-degree-of-freedom gyro. It represented a major innovation because of its minimal residual drift characteristics.

When AC Spark Plug became interested in inertial systems, the company went back to Draper's work, modified it to produce a guidance system to be monitored by a self-contained automatic steller observation device. This star-watcher, called SIBS, was a great-circle navigation system with closed-loop navigational components.

The first SIBS was installed in an Air Force plane in 1955, but its size and weight were against it. The SIBS equatorial plane required five gimbals, making the gimbal package 60 in. in diameter. The associated electronics required 85 cu-ft and the entire system weighed over 2,700 lb.

A simpler version of SIBS was proposed for long-range cruise missiles—air-breathing missiles such as Regulus and Mace, which travel at speeds between 600 and 1,000 mph and always stay in the earth's atmosphere. By incorporating a vertical-launch navigational scheme with a platform suspension of three gimbals instead of five, AC slimmed the weight to 500 lb, reduced the gimbal unit diameter to 27 in., the electronic volume to only 8 cu ft.

AC then went on to develop inertial systems, with floated gyros, for the Air Force's Mace and the Navy's Regulus.

When the switch came to ballistic missiles, AC again looked to the floated gyro. Company engineers reasoned: if the gyro had residual drift characteristics which made it capable of guiding a long-range cruise missile over its nearly 2-hour flight, it could certainly handle the relatively simple task of guiding a ballistic missile over the powered portion of its flight, which is measured in seconds.

Working with MIT's Instrumentation Laboratory, the company developed an adaptation that was accepted as a backup guidance unit for the Atlas missile. But before the project was six month old, the Air Force changed plans, directed that the unit be revised for Thor.

The switch left major characteristics of the system unchanged; a prototype was completed within nine months. Only three years after the ballistic system project was launched, Dr. Draper's floated gyros were guiding Thor missiles at Cape Canaveral.

---

measurement (the platform's balance is sensitive to the flick of a finger) and the means for this measurement. Simplified, the subsystem consists of three gyro accelerometers orthogonally mounted on a gyro-stabilized platform which has a known spatial orientation with respect to the launch point. The accelerometers provide direct and accurate measurements of missile accelerations and fuel mass-flow characteristics. A small on-board computer operates on the accelerometer outputs to provide missile steering and engine cutoff signals.

Constant factors affecting the missile during the free-fall portion, such as gravity and earth's rotation, are treated as input information rather than problems that the computer must solve. Computer size has been reduced because Thor also uses the "Q" system of navigation, a complex classified system in which more complicated navigational computations are completed on the ground before launch.

The stabilization servo loops, one to each of the three axes (Figure 4), work this way to maintain the reference platform: when the gyro experiences an angular movement about its input axis, the resulting output voltage from the signal microsyn serves as a signal to amplifiers controlling the gimbal torque motor. The motor reorients the proper gimbal to reposition the platform and thus maintain it in a fixed orientation with respect to inertial space.

The gyro signal microsyn output is applied to a stabilization servo-drive amplifier that converts the ac error signals to a dc differential current. This controls the field excitation of the torque generator which functions as a rotating power amplifier, producing a reversible dc control voltage for the torque

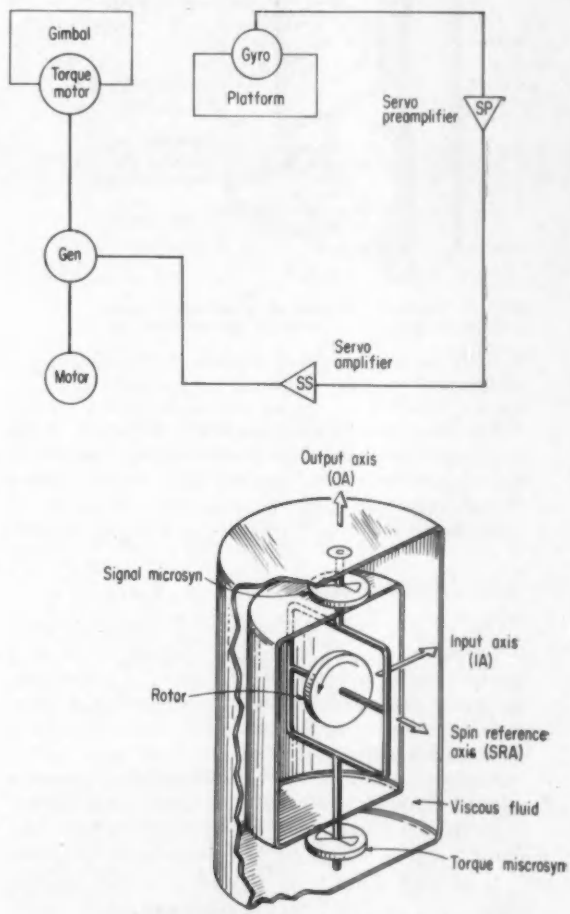


FIG. 4. Stabilization servo loop that maintains reference platform in position with a close-up look at the stabilization gyro.

motor. The latter, in turn, provides the rotation necessary to null the gyro output.

Measurements of acceleration are made by a gyro accelerometer servo loop, which is similar to the stabilization loop except for the addition in the ground support equipment of an integration channel for pre-flight calibration. The channel's function: to drive the accelerometer case with an adjustable signal supplied from a potentiometer rather than a signal from the accelerometer signal microsyn. The extra channel permits the loop to operate with zero position error in a static environment.

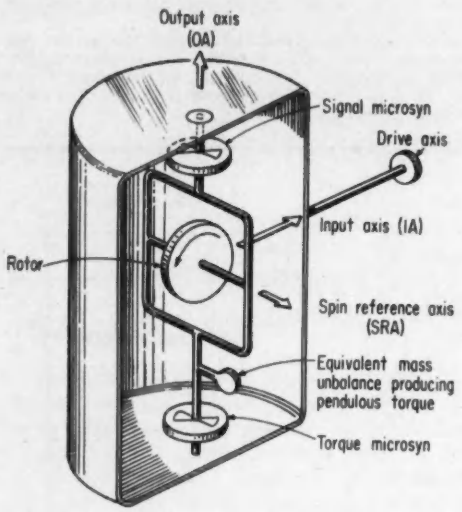


FIG. 5. Schematic diagram of accelerometer gyro. It has an unbalanced mass along the spin reference axis.

As the missile accelerates along the three input axes, the accelerometers perform their measuring function. Their drive motors also rotate synchro transmitters. Associated control transformers in the computer repeat the shaft rates of V_g computation.

The floating gyros

One of the major problems in an inertial system is precession or drift of a gyro. Opinion varies as to the best way of minimizing precession. For example, the Army group at Redstone Arsenal prefers air bearings for the gyros in the inertial system of the Redstone and Jupiter missiles.

Achiever, however, uses a refinement of Draper's original concept (see box) of a floated, integrating, single-degree-of-freedom gyro. Such a device uses about 3 oz of Flurolube, a commercially available fluid of high density, to separate the 6-lb helium-filled "can" or float from the outer case. Two pivots on each end of the spin axis have little to do except hold the can in place. Viscous damping is controlled by the Flurolube viscosity and the clearance between the float and the gyro case.

The input, output, and spin axes of the stabilization gyro form a right-handed orthogonal system of the order *IA, OA, SRA* (Figure 4). If the gyro senses an angular displacement about its input axis, it will precess about its output axis in an attempt to align its spin axis with the input axis. Since the stabilization gyros are mounted on a platform, exterior forces tend to produce angular displacements of the platform and rotate the gyro around its input axis, causing the case to rotate about the output axis. A signal microsyn mounted on the output axis generates a voltage directly proportional to the magnitude of the displacement of the gyro float from its null position. This output voltage is used as an error signal in the stabilization servo loop.

The accelerometer gyros (Figure 5) are similar. The major difference—other than size—is the addition of an unbalanced mass along the spin reference axis to make the gyro sensitive to linear acceleration in the direction of the input axis. For any input acceleration acting on the gyro case along the input axis, a pendulous torque is exerted about the gyro output by the unbalanced mass axis. As soon as this torque is sensed, the float tends to be displaced about the output axis.

An error signal proportional to the sensed acceleration is generated in the signal microsyn and transmitted through slip rings to a servo drive, which, in turn, rotates the case about the input axis. This sets up a gyroscopic precession torque opposite in direction and equal in magnitude to the pendulous torque, effectively preventing appreciable deviation of the float from its null position. The angular rate at which the case rotates is proportional to the input linear acceleration.

Once acceleration is measured, the computer integrates once to get velocity. Distance integration is not needed because of preset constants available for any ballistic trajectory. Computers in inertially-guided air-breathing missiles, on the other hand, must complete the second integral and as a result are more complicated.

Performance record

Reliability of the system can be judged best on the firing range. Of a total of 24 Thors recently launched, 15 flights were successful, three partially so, and six failed (not all failures, however, were attributable to the guidance system).

Exact effectiveness of the Thor is, of course, a military secret. But, say AC engineers, if a Thor with nuclear warhead were fired at Milwaukee (where Achiever is built) from a point 1,500 miles away, some people in the city might live to know what happened—but most wouldn't!

EMISSION SPECTROSCOPY

speeds control of metals production

THE GIST: Continued improvements in instruments and techniques makes emission spectroscopy a valuable control procedure in metallurgical manufacturing processes. Net results: savings of millions of dollars in performing analyses and in improved production. Analytical determinations of composition are returned on a routine basis to the production location in four minutes after receipt of the sample (via pneumatic tube). The author describes principles and applications of emission spectroscopy in the aluminum industry; on trial is an analog computer and digital readout system connected directly to the spectrometer. This system transmits analysis information via Teletypewriter to the production area.

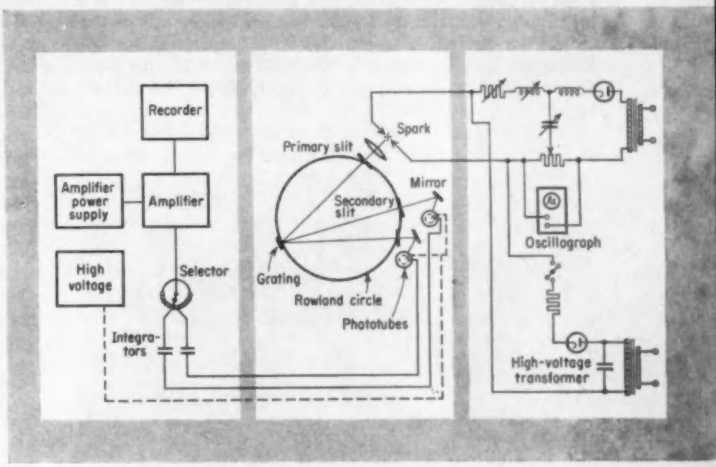


FIG. 1. Simplified schematic of photoelectric polychromator or direct reader, one of the newer developments in emission spectrochemical instruments.

J. R. CHURCHILL, Alcoa Research Labs., Aluminum Company of America

Recent developments in emission spectroscopy have changed industrial analytical chemistry from a post-mortem inspection to a true up-to-the-minute control procedure. Many production processes include an integral analytical laboratory to measure product composition. Some laboratories use wet-chemical techniques, but these may take so long that the batch being measured may have been completed before its composition could be determined. The analysis is then of historical import: if the composition is within specs, the batch is used; if not, it is rejected as scrap. On the other hand, laboratories using emission spectrochemical instruments produce compositional information on a current basis, a matter of a few minutes between drawing the sample and getting answers. Variations in composition are detected and corrections made without slowing the production process.

Principles of emission spectroscopy

The fundamentals of emission spectroscopy are rather simple: when an element is subjected to an arc, spark, or flame of sufficient energy, a portion of that energy is absorbed by the atoms or ions and subsequently released as radiant energy. This radiant energy occurs at fixed frequencies uniquely characteristic of the atoms and ions involved. Frequencies emitted by various elements are sufficiently different and well known that they can easily be sorted out and identified with conventional optical instruments. These frequencies are ordinarily referred to as lines, expressed in terms of wavelength.

The simplified schematic of a photoelectric polychromator, Figure 1, shows the operation of that emission spectrochemical instrument. At the right is an excitation source that generates a spark. The sample in the spark's discharge zone emits radiant energy characteristic of the elements in the sample. The total radiant energy is focused through the primary slit onto a grating. The grating separates the emitted energy into discrete frequencies, each of which goes through its associated secondary slit and is then reflected to a phototube. Phototube output charges an integrating capacitor, and the accumulated charge is selected and recorded. The recorded charge for each element is a function of the concentration of that element. In spectrographs, however, a camera and photographic film are used in place

of the photoelectric receivers, and the blackness of the spectrum lines must be measured to deduce concentrations.

All metallic and most semimetallic elements emit lines within the spectrum range of 2,000 to 8,000 angstroms when excited in conventional arcs or sparks, while most nonmetallic elements require special equipment for their excitation and measurement. Only metallic and semimetallic elements will be discussed, with the understanding that emission-spectroscopy techniques can be applied, with sufficient elaborate equipment, to any element.

Since spectrum lines uniquely characterize those elements present in a sample, emission spectroscopy provides an elegant qualitative tool. It is specific in the absolute sense, an attribute sought but seldom found in the search for analytical methods. The appearance of an element's spectrum lines is absolute proof of the presence of that element in the radiation source. Moreover, emission spectroscopy happens to be a sensitive technique for most elements.

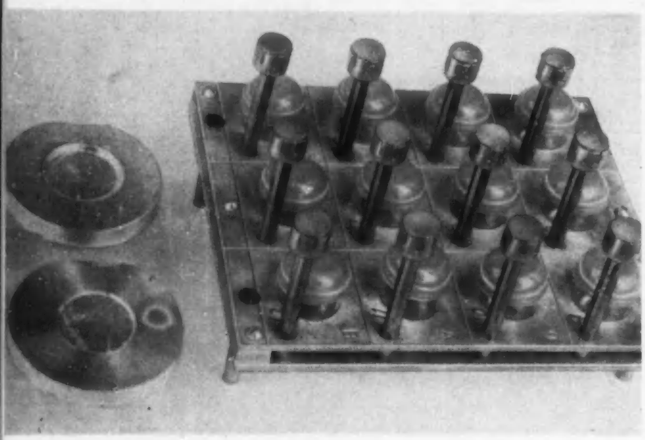


FIG. 2. Sample electrodes used with spectrochemical instruments. Upper left—as-cast metal sample; lower left—metal sample after machining and sparking; right—briquetted mineral samples mounted in sparking holders and ready for analysis.

The quantitative aspects of emission spectroscopy are more complex. As might be expected, a spectrum line's intensity increases as the concentration of the element producing the line increases. Unfortunately, however, the increase in intensity is not necessarily proportional to the increase in concentration. This is partially attributable to the phenomenon of self-absorption—the nonlinear absorption of the line by the element producing it. Another complicating factor is the influence of other elements on the spectrum intensity of a given element. This effect, the matrix effect, is actually a number of different phenomena, many of which are not well understood. Some matrix effects result from incomplete separation of the line of the element sought from other radiations. Some are attributable to the influence of sample composition on the effective energy available for excitation in the discharge zone. Others are caused by compounds formed between the element sought and other elements present in the spark column. A further complication arises by not being able to introduce the sample into the radiation source in such a way that elemental concentrations in the luminous region are representative of concentrations in the sample. An example of this latter point is that the more volatile elements vaporize more rapidly from an arc electrode than the less volatile elements.

Despite the complications mentioned and the lack of complete theoretical rationalization, it has been found that, for a given matrix, intensities can be related to concentrations, and that this relationship can be measured and reproduced with sufficient reliability to make quantitative spectrochemical analysis feasible in a wide variety of industrial applications. Reliability is achieved by close control of the significant variables, careful calibration with samples of known composition, and internal standards. An internal standard is the line of an element present in known concentration. The ratio of the line of the element sought and the internal standard corrects for variables having a similar effect on the two lines. Internal standards never behave precisely like the lines of the elements sought, but they generally improve net accuracy after all other practical steps have been taken to minimize the variables of excitation and measurement.

Sample treatment

All emission spectroscopic methods are similar in principle but differ in detail, mainly in sample treatment and in the means of exciting the spectrum. When flame excitation is used, a solution of the sample is usually sprayed into the flame. For metals, arc or spark electrode pairs are fashioned from the sample itself. Often the spark or arc is formed between a flat, machined surface of the sample and a rod of some noninterfering material such as graphite. This arrangement is widely used, especially in the aluminum industry. Such nonmetallic samples as minerals, salts, and powders may be packed into cupped electrodes, mixed with conducting materials and briquetted, or put into solution. Figure 2 shows some sample electrodes.

Samples received as solutions, or for reasons of convenience or necessity put into solution prior to analysis, may be handled with arcs and sparks as well as flames. This may be done by spraying solution into the arc or spark, by feeding solution through capillary orifices into the discharge zone, by sparking directly to the solution surface, or by evaporating an aliquot of the solution on the electrode surface prior to excitation. Sometimes the most practical procedure is to simply evaporate the solution and treat the dry residue by one of the methods mentioned for solid samples.

In typical industrial control situations, speed and economy dictate that sample preparation be kept to a minimum. Consequently, where possible, the sample material is used in the form in which it occurs in the production process.

Excitation methods

A flame is a relatively low energy source. While most elements at sufficient concentration produce a flame spectrum, the flame's practical usefulness in industrial control is limited mainly to the more volatile and easily excited elements. The principal advantages of the

flame are its inherent stability and its adaptability to in-line control or monitoring systems. The flame generally produces a much more constant radiation than arcs or sparks and can be operated continuously for an indefinite period. Thus, it is an ideal source for monitoring the sodium content of a flowing aqueous solution. On the other hand, it is almost worthless in the general analysis of metals. Application of flame sources may be expanded by using gas combinations (hydrogen-fluorine and cyanogen-oxygen) producing higher temperatures and by combining flame with arcs and sparks.

The direct-current arc is essentially thermal in nature, provides high sensitivity for most elements, and applies to a variety of samples. Its principal disadvantages are the lack of stability and the preferential volatilization effects encountered with many materials. The dc arc is generally used when no other available source gives the desired sensitivity or when the nature of the sample precludes other excitation systems.

The most widely used excitation source is the high-voltage spark. Its short-range stability (say, within a second) is less than that of flames, but it is the most precisely reproducible excitation source available that has the sensitivity and element coverage required for most industrial applications. Modern spark units operate at peak voltages between 10,000 and 30,000 volts and are equipped with elaborate controls and regulating equipment (see Figure 1) to insure that the number of discharges per sec and the contour of each discharge (in terms of voltage, current, and time) are precisely reproduced.

In metallurgical control work, the high-voltage spark is used whenever possible. When more sensitivity is required for certain elements, adding inductance makes the discharge more arclike. If necessary, two successive exposures are made, one a sparklike discharge for higher concentrations and the other an arclike discharge for trace elements.

Emission spectroscopic instruments

Three broad types of optical assemblies are important in industrial spectroscopy:

- special spectrometers for flames
- grating and prism spectrographs
- large grating polychromators

Since flame spectroscopy usually involves simple spectra and few elements, the requirements of the optical system are correspondingly small. In routine determination of alkali elements, for example, interference filters often provide all the wavelength discrimination required. For more general flame work, relatively small, low-dispersion prism and grating spectrometers are usually adequate.

Numerically the most often-used optical system is the spectrograph. The term spectrograph is restricted to those instruments that produce a spectrogram, a panoramic photograph of the spectrum. With the exception of flame photometry and a few other special cases, virtually all industrial spectrochemical analysis was done with spectrographs up until the modern photoelectric polychromators became available. Even today, there are many more spectrographs than polychromators used in industrial analysis.

The most popular and the best spectrographs are grating instruments. Spectrographs come in many shapes, sizes, and qualities, ranging from the small instruments used in undergraduate physics laboratories to the large and elaborate ones required for the complex spectra of atomic energy fuels. Prism instruments and smaller grating instruments are applicable when their lower resolving power and less favorable line-to-background (signal-to-noise) ratio can be tolerated.

Much useful analytical information can be obtained by visually examining the spectrogram, but in most industrial control work a densitometer is required for quantitative measurements. This is simply an apparatus for measuring the blackness of the line images on the film or plate. Usually it is combined with a projection system for viewing a magnified image of the spectrum. Comparator-densitometers are readily available for all types of spectrographs.

The densitometer produces a result in terms of optical density or transmittance of the measured spectrum line. This result is converted to a number proportional to radiant intensity in the discharge source through calibration data obtained from calibration exposures of known relative intensity. These relative intensities are converted to concentrations through calibration data taken on spectrograms of samples of known concentration. Thus, there are two calibrating steps necessary, one to convert densitometer readings to relative intensities (relative intensity ratios when an internal standard is used) and a second to convert intensity data to concentrations. When relatively low analytical accuracy is required, the first step, known as emulsion calibration, is sometimes omitted. But when high accuracy is sought, emulsion calibration is important because variation in emulsion sensitivity is the source of a considerable part of the analytical error.

The relationship between exposure and blackening of a photographic emulsion varies widely with wavelength, temperature, humidity, previous history of the film or plate (manufacturing variables, age, storage conditions, etc.), sharpness of the line image, proximity of other images, light-source intermittency, and variables in developing and fixing the film or plate. In industrial control work, it is usually necessary to compromise between calibration accuracy and operational efficiency. Elegant calibration is generally impractical because of time and cost. Fortunately, some, but not all, errors of emulsion calibration are nullified by the subsequent calibration with known standards.

A variety of apparatus—including calculating boards, nomographs, charts, tables, and drum-type calculators resembling squirrel-cage slide rules—is used to carry out the computations involved in calibration and analysis. With suitable equipment, the computation requires only a few seconds per element, once the calibrations are established.

For many industrial control applications the spectrograph-densitometer combination is becoming obsolete. While photography has advantages in nonroutine applications where a panoramic view of the spectrum is needed or where it is not known in advance what elements are to be determined, the spectrograph-densitometer system is not ideally suited to routine quantitative work. A better approach is the direct photoelectric measurement of line intensities instead of interposing a photographic step and then making a photoelectric measurement on the photograph.

Photoelectric polychromators (direct readers), Figure 3, are spectrographs in which the camera has been replaced with receiver slits and electron-multiplier photo-

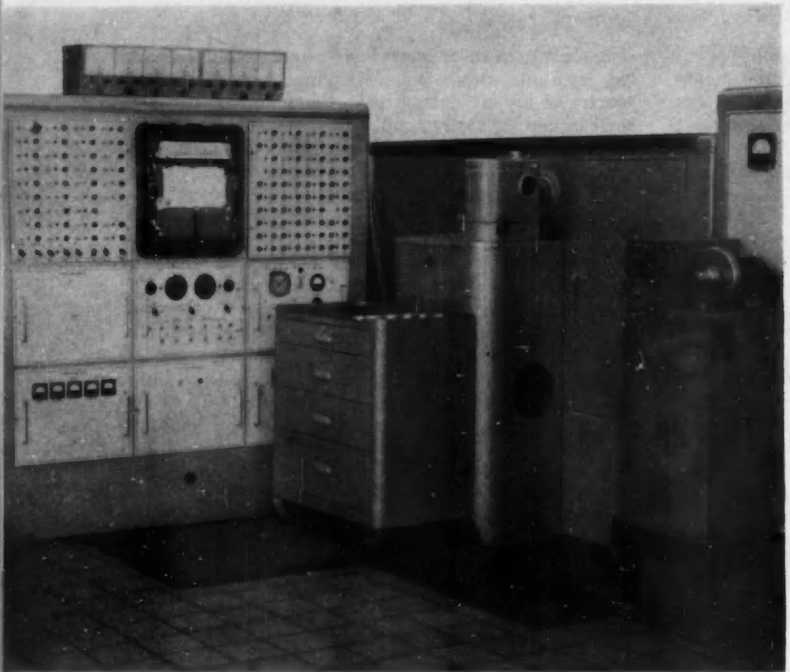


FIG. 3. Production Control Quantometer installed at Alcoa Research Labs. Console contains basic control and measuring system. Meters above console are part of high-speed alloy determinator. Spectrometer is at right of console, with excitation equipment partly shown at right of spectrometer.

cells. Such photocells have sensitivities several orders of magnitude greater than nonmultiplier photo cells. The most successful instruments employ concave or plane gratings, although photoelectric attachments are made for converting prism spectographs to rather simple direct readers. At this time there are only three makes of direct readers used to any significant extent in the United States. These are made by Applied Research Labs., Inc., Baird-Atomic, Inc., and Jarrell-Ash Co. A number of instruments are being developed in Europe, and a few have recently been imported.

Polychromators can do almost any job a spectrograph can do with a densitometer and other auxiliaries and can do it more accurately and rapidly provided that the type of job was anticipated in the design of the instrument. The main exceptions to this are general qualitative analysis and the pursuit of the lowest detectable quantities of impurities. Qualitative analysis is usually impractical with polychromators because of the number of photocells required to cover all elements conceivably of interest and the fact that the spectrograph is so satisfactory in this capacity. In seeking maximum sensitivity of detection, photoelectric polychromators suffer from the inherent disadvantage of including more spectral background in the measurement. This can be largely eliminated in an instrument specifically designed for maximum sensitivity. Also, the effect is partially compensated for by the high precision of such instruments. Sensitivity of detection in spectrochemical analysis, as in most other fields, is largely determined by the precision of measuring the difference between signal plus noise and noise alone. The polychromator with its superior inherent precision can tolerate more noise (spectral background) than can a spectrograph.

Typical modern polychromators have 40 or 50 photocells and 100 or more measuring channels. The number of photocells is largely determined by the number of different elements, although more than one photocell may be required for the same element for different types of samples, different modes of excitation, or widely different concentration ranges. The large number of channels is required merely for speed and efficiency. By having more than one measuring channel for a given element, the operator can rapidly switch back and forth between jobs requiring different calibrations and can change sensitivity adjustments for one job without disturbing the adjustments established for another.

Polychromators are expensive. Typical installations, including auxiliary equipment, usually cost well over $50,000. This cost may be halved if only one particular type of analysis and only a few elements are involved. However, the general tendency is to make the instrument sufficiently versatile to take care of all possible analyses required.

How Alcoa uses spectrochemical analysis

By the end of the World War II, Alcoa had installed 44 spectrographs and had made tens of millions of spectrochemical tests. Over 80 percent of metal analysis was being done spectrographically, and many millions of dollars had been saved by doing analyses spectrographically instead of chemically. The spectrograph represented an important step in the change from historical to control analysis. The spectrographic analysis of a typical aluminum alloy could be accomplished in less than 10 min under very favorable circumstances; but in sustained, everyday practice, it was found that 15-min service was about the best that could be expected. This was sufficiently fast in many cases to provide for adjustment or corrective action in the production process.

In aluminum alloys it was found that spectrographic methods were more precise than routine chemical methods below 0.3 percent, about equal from 0.3 to 1.5 percent, and inferior above that point. Of course, this comparison varied with the element and the alloy, but held to a first approximation in most cases. Among the important aluminum alloys were those containing several percent of copper, zinc, silicon, and magnesium. Spectrographic methods for these elements were found somewhat inadequate at concentrations in the neighborhood of 4.0 percent and higher. It was necessary, therefore, to supplement spectrographic analysis with chemical determinations.

The benefits gained from the speed and economy of spectrographic analysis led to intensified research aimed at improving the precision and speed of spectrochemical analysis to the point where it could completely super-

sede chemical analysis and thus be used as a process control to the fullest extent. Alcoa investigators, like many others, found the most serious weaknesses of the spectrographic method to be in the photographic process. The complex and variable relationship between radiant intensity and photographic response and the time required for photographic processing, calibration, measurement, and computation made the elimination of photography an obvious goal.

In 1941 Alcoa started working on the development of photoelectric emission equipment. This work was largely theoretical and somewhat speculative until the electron multiplier phototube was perfected during World War II and later made available for civilian use. At that time ARL built an eight-receiver prototype polychromator of flexible design for Alcoa. Work on this instrument at Alcoa Research Labs. showed that the basic design was practical, and the analytical technique it made possible was applicable to the control analysis of aluminum alloys. Accordingly, a series of four instruments (later called Research Quantometers) were designed cooperatively and built by Applied Research under contract with Alcoa.

The early Alcoa Quantometers were put to use in four locations; Alcoa Research Lab., two large fabricating plants, and a large and highly diversified foundry. Each was almost immediately successful, and this led to the rapid conversion of virtually all metal analysis in those plants from a combination of chemical and spectrographic analysis to photoelectric spectroscopic analysis, or quantometric analysis as it is now called.

As a result of in-plant investigations carried out on the Research Quantometers, developed cooperatively with Applied Research Labs., Alcoa was able to specify the requirements of more elaborate, but less flexible, instruments for production control. These subsequent instruments, known as Industrial Control Quantometers, were custom-built to meet the needs of each application. Since most Alcoa plants had a rather large diversity of alloys and other materials to analyze, the instruments were necessarily elaborate, often involving 40 or more different wavelengths, 100 or more measuring channels, and three or more independent arrays. Most Alcoa Quantometers were equipped to handle virtually all commercial alloys of aluminum. In addition, arrays were provided for such other materials as magnesium-base alloys, cast iron, zinc, elemental silicon, ores, and process solutions. Sufficient controls and switchgear were provided to change from one type of analysis to another with minimum time loss. This was essential, since to operate on a control basis the analyst had to be able to handle each analytical job without significant time loss, regardless of sequence and without knowing what type of sample would arrive next.

In a typical Alcoa plant the Qauntometer is located at a convenient location providing a good environment for the equipment and personnel. To achieve high speed service, pneumatic tubes transport samples and telephone, Teletype, or pneumatic tubes transmit results. Samples are taken at key points in the production process.

Most Alcoa laboratories operate with some guaranteed maximum on the elapsed time for issuing an analysis in control work. A sample can be analyzed in a minute or less, but since there is usually more than one source of samples, the problem of coincidence of sample arrival dictates a somewhat longer average time. A large sheet mill requiring several hundred analyses per day may operate on a 4-min guarantee. This means that when a control sample arrives through the pneumatic tube, it will be machined, analyzed, and the results transmitted within 4 min, even though a number of samples may arrive almost simultaneously.

Samples are taken at key points in the production process at sufficient time intervals to detect and correct variables in production that affect product composition. Depending on the size and nature of the operation, this may mean one sample per 50 pounds of production or one sample per several thousand pounds.

With a fairly constant total work load of sufficient volume, quantometric laboratories can produce 75 or more determinations, including historical analyses, per man-hour. As the emphasis on control and, consequently, on speed of service increases, fewer determinations are produced per man-hour. Alcoa laboratories average over 40 determinations per man-hour. This compares with an average of less than five determinations per man-hour by wet chemical methods. These figures include analysis, sample preparation, supervision, and clerical time.

With the exception of one small plant operating on spectrographic control, metal production throughout Alcoa is controlled by quantometric analysis. Twenty-three instruments of the Quantometer type produce over 10,000,000 determinations annually. Nine more Quantometers are used in mining, refining, and research. In the aggregate, about 90 percent of the

PRECISION OF ROUTINE QUANTOMETRIC ANALYSIS IN ALCOA CONTROL LABORATORIES

Element	Average concentration, percent	Standard deviation, percent
Copper	0.25	0.0037
	4.7	0.040
Iron	0.56	0.010
	0.65	0.010
Silicon	12.0	0.090
	1.2	0.009
	0.53	0.008
Manganese	1.2	0.015
	0.048	0.0006
Magnesium	2.8	0.027
Zinc	6.3	0.067
	0.038	0.0009
Nickel	2.5	0.027
	0.047	0.0009
Chromium	0.25	0.0025
Titanium	0.047	0.0010
Vanadium	0.077	0.0014
Lead	0.035	0.0014
Tin	0.044	0.0011

Note: These data were obtained by interspersing replicate tests in routine control work of 16 laboratories over a six-month period. Each entry represents more than 1,200 tests.

analyses made in Alcoa are made quantometrically. This has saved many millions of dollars in analytical costs with a demonstrable net gain in reliability. Even larger benefits have been achieved in production operation by replacing historical analysis with control analysis.

The matter of analytical accuracy deserves some further mention, since this was the area in which spectroscopy was deficient in the pre-Quantometer era. Today's Quantometers are consistently able to produce analyses to a precision of 1.0 percent or less of the amount determined (measured as the coefficient of variation). This compares favorably with any other technique in general industrial use. In Alcoa a careful check is made continuously on the precision and accuracy of all laboratories. The table shows the average precision attained, based on thousands of determinations in the course of routine operation. Accuracy is measured by periodically selecting random samples from each Alcoa laboratory and analyzing these samples by umpire methods at Alcoa Research Labs. These tests have shown slightly but consistently improved accuracy in the past few years than was achieved in the very best years of all-chemical analysis.

Rosy as this picture seems, the precision and accuracy of quantometric analysis can and should be further improved. The next significant improvement must come in sampling and excitation techniques rather than in the polychromators. As in most other industrial applications, the representativeness of the sample, its nonuniformity, and its structural variations introduce a far greater proportion of observed errors than do the variables in discrimination and measurement of spectrum lines. Unfortunately, the sampling problem is not merely that of obtaining a sample whose composition actually represents what it purports to represent; the analysis obtained is considerably affected by physical structure and states of combination of the elements. Even heat treatment, annealing, and cold-working have significant effects on results. Presently such effects are circumvented by employing samples and standards prepared under carefully controlled conditions. When samples of unsuitable or unknown metallurgical history are submitted for analysis, they are remelted and cast under standard conditions or analyzed by some other technique.

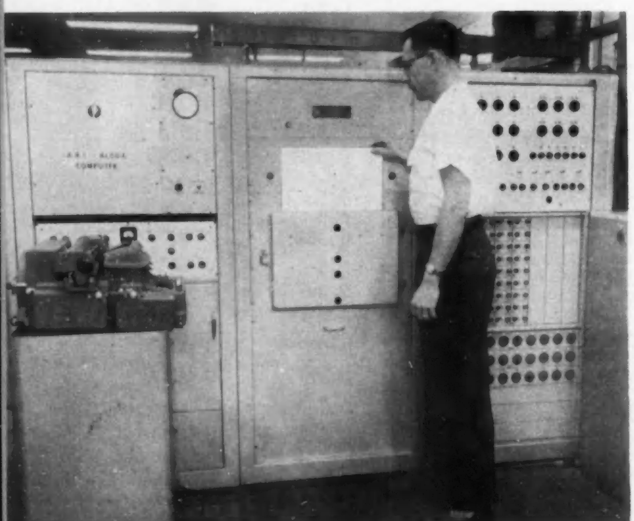


FIG. 4. ARL-Alcoa computer controls Quantometer operation. Command card being inserted by operator sets up and programs entire analytical cycle, including spectrum excitation, intensity measurement, computation, and printing of final report.

Analog-computer readout

Currently, most Quantometers produce a strip-chart record or other scale reading that must be interpreted. Even the typed records produced by some Alcoa instruments give the results in terms of arbitrary intensity units. Only in rather simple specialized operations do these instruments automatically produce final results without interpretation or transcription by the operator. To have the instrument do the job of interpretation and transmittal requires the insertion of a computer between the output of the Quantometer and the final recording device. A complete analog computer and transmitting system, Figure 4, has been designed by Alcoa and Applied Research Labs., and has now been installed at Alcoa Research Laboratories.

With this computer system and a Production Control Quantometer, the analytical operation is initiated by placing the sample in the spark stand as usual. A command card is inserted that instructs the instrument and computer concerning the sample type, the determinations required, the number of decimals to which the various concentrations are to be expressed, and such other details as choice of excitation conditions.

After insertion of the command card, the instruments take over. As usual, spectrum-lines intensities are represented by cumulative charges on capacitors during sparking, and the sparking period is controlled by the internal standard. At the termination of the sparking period, the voltages on the integrating capacitors are successively fed into the computer which in turn actuates typewriters both in the laboratory and at the locations to which results are to be transmitted. The computer bases its calculation on mathematical relationships between radiant intensity and concentration that have already been determined. These relationships are expressed as equations fed in by the command card.

Also included is a refinement not usually included in present-day quantometric computation. The minor effects of the concentration of one element on the spectral behavior of another are computed and corrected for when such effects are significant. An extra benefit from such equipment is the ease of producing tapes and/or cards for summarization, replication, and statistical computation as a part of the automatic sequence.

Spectrochemical analysis can be viewed as one stage in the process of developing the automatic production system. It represents a great advance over the previous methods used but still leaves much to be developed in pursuit of the ideal system of composition control. In this pursuit much effort is put into improvement of control laboratories, but the ultimate objective is their elimination. Theoretically at least, virtually all laboratory determinations made for control purposes can be executed by automatic devices integrated into the production process. Spectrochemical devices such as photoelectric polychromators represent a step in this direction, but to them must be added automatic sampling devices and equipment for translating its signals into actions which regulate the composition being measured.

Static switching applied to a seven-station brake pedal machine

Static Switching Passes A Maintenance Test

JOHN ZURBRICK, McGraw-Hill News

Pontiac Div. of GM put static switching on a production machine tool to test maintenance requirements. The result: no control maintenance in 18 months of operation.

Static switching to sequence operations of a seven-station indexing brake pedal machine was installed by Pontiac Motor Division of General Motors with a definite purpose in mind: compare maintenance requirements and control system life in an on-the-floor production machine. During 1½ years of machining brake pedals, with 1½ million switching operations, the static switching units required no maintenance.

In this trial installation, Westinghouse Cypak units –for sequencing–were combined with Type "Z" interposing relays for output. Cost dictated the combination. A fully static system of Cypak and preamplifiers would have raised the price of the control unit over twice that of a conventional system with relay switching. The panel with Cypak and Type "Z" relays still cost more than 1½ times a conventional control.

Westinghouse designed, built, and tested the panel for the brake pedal machine; Trio Tool Company, Detroit, designed and built the machine specifically for Pontiac. The two units combined at the Pontiac plant.

"De-bugging and final adjustments," said A. H. Waineo, Trio Tool chief engineer, "were much easier with this system than with a relay system." An error in installation of two Cypak units showed up in a final check run on an operation simulator. Replacing them ended difficulty with the static switches.

The machine was designed to drill, ream, hollow-mill, chamfer, and tap the 1958 model brake pedal. Changes in the 1959 pedal resulted in the removal of the hollow-milling and tapping operations and the addition of back-countersinking. Two pedals are machined simultaneously at each of the seven stations. At station 1, one pedal is removed, the other flipped over, and one added–manually. Each pedal makes two complete counter-clockwise revolutions around the table. One operator loads and tends the machine.

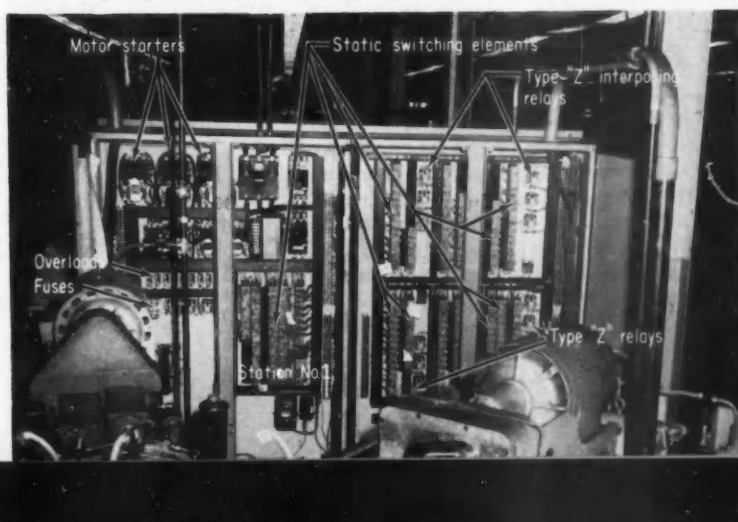
The changes made on the machine for the 1959 pedal were accompanied by changes in the Cypak circuits. And a probe wire was added to check after each cycle if the tip of the back-c'sink tool had broken off. This necessitated working circuits for the probe signal and sequencing into the existing Cypak board of station 3. These changes were made particularly easily because of the static switching, according to Les Thomas, head of Pontiac's Electrical Department.

The floor electrician attending this machine sums up the maintenance picture this way. During his eight-hour shift, the machine had an average of one call per week (two calls a week, for both shifts during which the machine was running); usually the trouble stemmed from a broken or bent probe wire or from the heater (hydraulic pump motor starter resulting from too high hydraulic pressure when the machine is started up cold). Average downtime was 20 minutes, he said. None of his calls involved the static switching.

Maintenance records on the brake pedal machine verified this performance. Here is a month-by-month tabulation of troubles reported on the brake pedal machine over an 8-month period:

July	Two limit switch troubles. Machine trouble.
August	Main safety switch—open circuit.
September	Heater—tripped. Relay overload—tripped.
October	Solenoid—burned out.
November	Machine trouble.
December	Heater—tripped. Limit switch—out of adjustment. Limit switch—wire broken. Hydraulic trouble.
January	Selector switch—switch off.
February	None.

The brake pedal machine is the only piece of production equipment at Pontiac using a static switching system. The company is now looking into new applications on equipment intended to remain in production for more than two years. Detroit Transmission Division of GMC has specified static switching to all machine tool builders supplying its two new transfer systems.



Machine control panel sits behind stations 6 and 7. Input from the limit switches is properly sequenced at each station in the Cypak units. Output signals go to the Type "Z" interposing relays and on to the motor controls.

Using the Root Locus —Part I

THE GIST: This two-part article deals with the practical application of root locus methods to closed-loop systems. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags (dead time). In this first part author Jawor shows how to interpret the locus diagram and uses it to determine three-term controller settings. Part II will show the determination of transient response and its application to multi-loop systems.

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In the design of a linear control system, the performance criteria can be expressed as constraints on the location of the roots of the system's characteristic equation.

The characteristic equation of a linear control syster is an algebraic one, rational or transcendental, in a complex variable s, with the coefficients in the equation representing functions of system parameters. The roots being dependent on these coefficients are thus functions of the parameters, but the effect of a change in the value of any parameter upon the roots is not immediately obvious. The graphical root locus method, introduced by Evans (Reference) to the design of control systems, permits the relationship between any system parameter and the roots of the characteristic equation to be readily visualized. Using this technique establishes the effects of a shift of parameter value or the insertion of additional elements in the system upon the location of the roots. It makes it easier to manipulate parameters so that the roots will coincide with points specified by performance criteria. When incorporated into the system, these values insure the desired performance.

Theory of root locus

The characteristic equation is obtained from the system's closed-loop transfer function by equating the denominator of the function to zero.

The closed-loop transfer function is built up from the transfer functions of all the system elements. Although there are a large number of linear elements in control systems, their transfer functions can be synthesized in the complex frequency domain from the eight basic forms listed in the Table.

The root locus of a system containing neither a distance velocity lag (DVL), nor distributed lag (DL), is constructed from the poles and zeroes of the system elements. If DVL and/or DL are present, phase-angle loci (Figure 1) are superimposed and any points where the phase angle is $180 + n\ 360$ deg (where $n = 0,1,2,3\ldots$) lie on the root locus. In both cases, the open-loop gain can be represented as a parameter on the locus.

If the characteristic equation is in the form

$$1 + G(s) = 0 \qquad \text{where } s = \sigma + j\omega \tag{1}$$

then on rearrangement,

$$G(s) = -1 = |G(s)| \exp \left\{ j \arg G(s) \right\} \tag{2}$$

where $|G(s)|$ is the modulus of $G(s)$ and $\arg G(s)$ is the phase of $G(s)$.

The root locus curve consists, therefore, of all points in the plane of the complex variables at which $|G(s)| = 1$ and $\arg G(s) = 180 + n\ 360$ deg.

If the system consists of n basic transfer functions, some of which are rational in series, then

$$G(s) = \prod_{i=1}^{n} G_i(s) \tag{3}$$

where $G_i(s)$ is of a form listed in the Table.

Separating rational terms (forms 1 to 6) from transcendental terms (forms 7 and 8), and denoting the frequency invariant gain element of $G_1(s)$ by K_1,

$$G(s) = K_1\, G_A(s)\, G_B(s) \tag{4}$$

where $G_A(s) = \prod_{i=2}^{m} G_i(s)$ is the rational part of $G(s)$

and $G_B(s) = \prod_{i=m+1}^{n} G_i(s)$ is the transcendental part of $G(s)$

If Z_i is a typical zero and B_i a typical pole of $G_A(s)$,

Basic Transfer Functions and the Root Loci

Form	Name	Function	s-plane representation	Example
1	Gain	K	Parameter on root locus	Voltage amplifier
2	Integrator	Ts^{-1}	First-order pole at $s = 0$	Ideal integrator
3	Differentiator	Ts	First-order zero at $s = 0$	Ideal tachometer generator
4	Simple lag	$(Ts + 1)^{-1}$	First-order pole at $s = -T^{-1}$	Temperature detecting element, with thermocouple in good contact with the protective pocket
5	Simple lead	$Ts + 1$	First-order zero at $s = -T^{-1}$	Theoretical P + D controller (with proportional band 100 percent)
6	Complex lag	$(T^2s^2+2\zeta Ts+1)^{-1}$	Two first-order poles at $s=-\zeta T^{-1} \pm jT^{-1}\sqrt{1-\zeta^2}$	Load with inertia and damping
7	Distance velocity lag (DVL)	$\exp(-Ts)$	Essential singularity (infinity-order pole at infinity)	Insulated pipe carrying hot liquid
8	Distributed lag (DL)	$\exp(-\sqrt{Ts})$	Branch point at $s = 0$	Heat exchanger

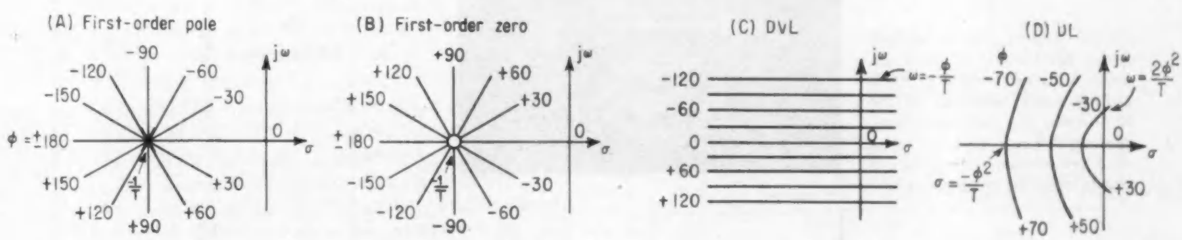


FIG. 1. A—The phase angle of the loci from a pole at $s=-1/T$. B—From a zero at $s=-1/T$. Note the inversion of phase-angle sign between the poles and zeros. C—The family of phase lines for a distance-velocity lag, where the spacing between the lines is $\phi=-\omega T$. D—Distributed lags give parabolic phase lines symmetric about the real axis.

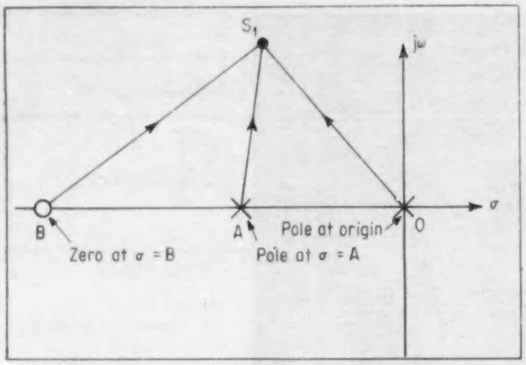


FIG. 2. For a simple system with two poles and one zero, the gain at the point s_i is determined from the moduli values of the vectors from the poles and zeros to the point s_i, and of the vectors from the origin to the pole A and the zero B. Substituted in Equation 5, these values determine the system gain.

then

$$G_A(s) = A \frac{\prod_{i=1}^{u} (s - Z_i)}{\prod_{i=1}^{v} (s - P_i)}$$

where u is the number of zeros and v the number of poles of $G_A(s)$ and

$$A = \frac{\prod_{i=1}^{v} (-P_i)}{\prod_{i=1}^{u} (-Z_i)}$$

To check whether a point is on the locus, the vectors from the poles and zeros to the trial point are drawn and the total phase angle at this point, including contributions from transcendental elements, is examined. The trial point is on the locus if the total phase angle is 180 + n360 deg, where n is an integer or zero.

For any point on the root locus the value of the frequency invariant K_1 can be found as

$$K_1 = \left[|G_A(s)| \times |G_B(s)|\right]^{-1}$$

$$K_1 = A^{-1} \frac{\prod_{i=1}^{v} |s - P_i|}{\prod_{i=1}^{u} |s - Z_i|} \frac{1}{|G_B(s)|} \qquad (5)$$

The gain at a point $s = s_i$ on the locus is obtained by substituting in Equation 5 the value of $G_B(s_i)$, the moduli values of the vectors from the poles and zeros of $G_A(s)$ to $s = s_i$, and the values of vectors from the origin to these poles and zeros (Figure 2).

Here is an example. A simple position-feedback system consists of a motor and a variable-gain amplifier, with a feedback link between the input and the output (Figure 3). Here

$$G(s) = G_1(s)G_2(s) \qquad (6)$$

where $G_1(s) = K_1$ is the amplifier transfer function,

$$G_2(s) = K_m/s\,(Ts + 1)$$

is the motor function, and T is the time constant of the motor. Thus

$$G(s) = \frac{K_1 K_m}{s(Ts + 1)} = \frac{K}{s(Ts + 1)} \qquad (7)$$

where $K = K_1 K_m$ is the open-loop gain. Hence the closed-loop function is

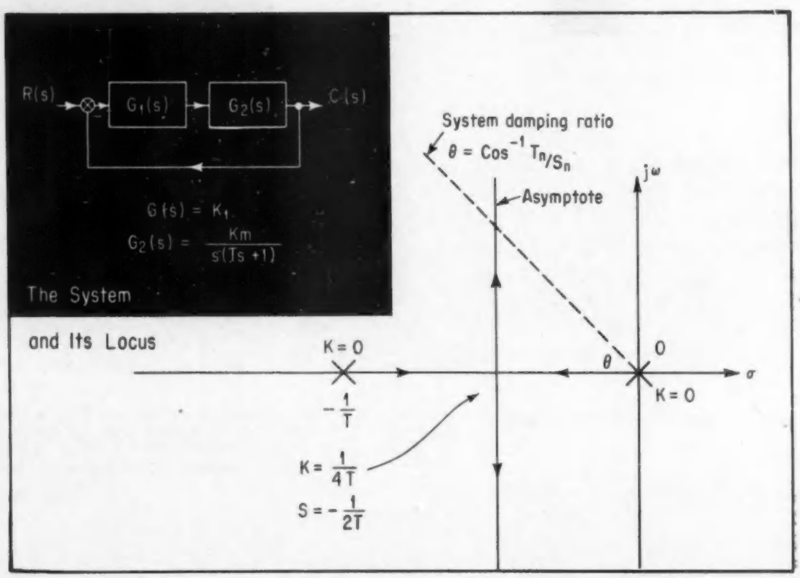
$$F(s) = \frac{K}{Ts^2 + s + K} \qquad (8)$$

The location of the roots of the equation

$$Ts^2 + s + K = 0 \qquad (9)$$

on the root locus is a function of K, and therefore also of K_1 (Figure 3). When $K = 0$, these roots are located at $s = 0$ and $s = -1/T$. As K increases they approach each other along the real axis, until they form a double root at $s = -0.5T^{-1}$ for $K = 0.25T^{-1}$. At this point the locus leaves the negative real axis, while the roots become complex. Since the real part

FIG. 3. A simple position, feedback system like the one shown in the insert has roots located at $s = 0$ and $s = -1/T$, when $K = 0$. As K increases, the root locus leaves the negative real axis; for values of K greater than $s = -1/(2T)$, it is parallel to the imaginary axis.



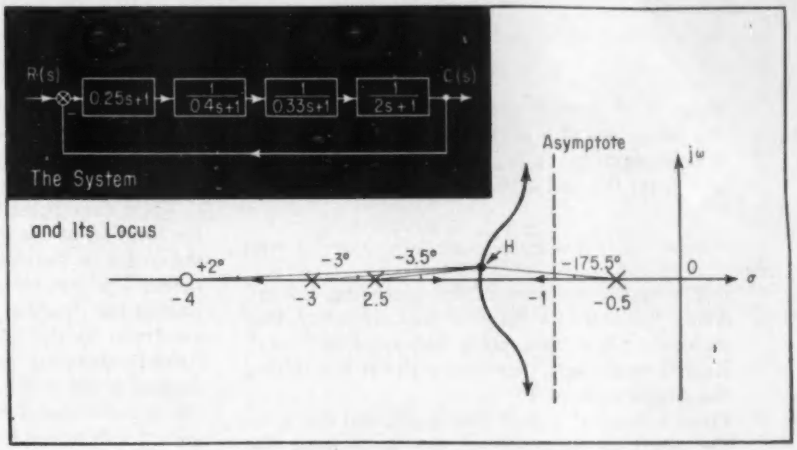


FIG. 4. For the system shown in the insert, the construction rules locate the poles, zeros, and locus asymptotes. The root locus is plotted by summing the phase angles from the poles and zeros to equal 180 deg. At point H the contribution from the zero at −4 is +2 deg. The poles at −3, −2.5, and −0.5 contribute −3, −3.5, and −175.5 deg, respectively. With the sum totaling 180 deg, H therefore lies on the locus. The point of critical damping in the system is where the root locus leaves the real axis—just below H.

of the complex roots is independent of K and the roots are conjugate, the loci for all values of K greater than $0.25T^{-1}$ are parallel to the imaginary axis and tend to infinity as K increases.

From the locus, it is immediately seen that the system will never become unstable, since the negative real part of the roots will never vanish; i.e. the locus will not intersect the imaginary axis. On the other hand, the relative damping ratio of the system, $\zeta_n = \sigma_n/s_n$, decreases with the increase in gain, since $|s_n|$ increases. The value of s_n is given by the vector from the origin to the point on the locus determined by K.

Thus for a given motor and a specified relative damping ratio, the amplifier gain K_1 can be determined. The value of K_1 is the point where the root locus meets the line of specified relative damping. This line passes through the origin, making an angle θ with the negative real axis, where $\theta = \cos^{-1}\zeta$. It should be noted that the roots of

$$Ts^2 + s + K = 0$$

are the poles of $F(s)$.

ROOT-LOCI CONSTRUCTION RULES

Root loci construction follows eight basic rules.

1. The loci are symmetrical with respect to the real (horizontal) axis.
2. If $G(s)$ is rational, i.e., $G(s) = KG_A(s)$, the number of branches of the loci is equal to the number of poles. (This is also true for transcendental $G(s)$ if the essential singularity is considered as a pole of infinite order at infinity, giving rise to an infinite number of branches.)
3. The loci start at the poles of $G_A(s)$ with $K = 0$ and end at zeros of $G_A(s)$ with K tending to infinity. If there is an excess of poles over zeros of $G_A(s)$, as is usually the case with control systems, the missing zeros are considered to be at infinity in the direction of asymptotes of Rule 4.
4. The asymptotes to the loci of $G_A(s)$ are straight lines with directions given by $\pm 180/(v - u)$ deg, where v is the number of finite poles and u the number of finite zeros of $G_A(s)$. The asymptotes for transcendental $G(s)$ for large values of $|\theta|$ are

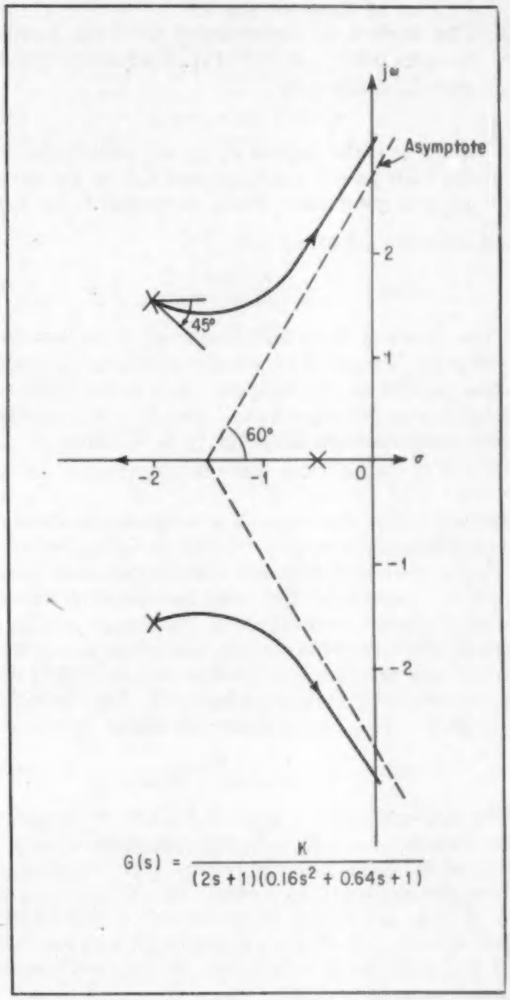


FIG. 5. In this example imaginary roots occur at $s=(-2\pm j1.5)$; the locus has an angle of departure of 45 deg and then runs asymptotically to the straight line inclined at 60 deg to the real axis.

those of its transcendental part $G_B(s)$ (that is, the phase loci of $G_B(s)$ for 180 deg).

5. The asymptotes of $G_A(s)$ intersect at a point $s = s_1$ on the real axis, given by

$$s_1 = \frac{\sum_{i=1}^{v} P_i - \sum_{i=1}^{u} Z_i}{v - u} \tag{10}$$

following the notation of the preceding section.

6. Along the real axis the root loci are alternating segments connecting poles and zeros of $G_A(s)$ located on the axis; they start with the one having the largest value of T.
7. Phase balance at a point near to the real axis gives the point of departure of the locus from the axis. (Contribution to the total phase of poles and zeros to the right of the point are balanced by that of those to the left.)
8. The angle θ_i of departure of the locus from a complex pole P_i, or that of approach to a complex zero Z_i, is given by

$$\theta_i = \pi - \phi_j, \qquad i \neq j \tag{11}$$

where ϕ_j is the angle at P_i (or Z_i) contributed by the finite pole P_j (or finite zero Z_j), or the phase angle of the transcendental element at P_i (or Z_i).

To show the use of the rules, let

$$G(s) = \frac{K(0.25s + 1)}{(2s + 1)(0.4s + 1)(0.33s + 1)} \tag{12}$$

Then the root locus will consist of three branches (Rule 2). Two of these are asymptotic to a straight line, parallel to the imaginary axis since $+180 \div (3-1) = \pm 90$ deg (Rules 1 and 4). The asymptote passes through the point $(-1, 0)$ since

$$\frac{(-0.5 - 2.5 - 3 + 4)}{3 - 1} = -1$$

(Rule 5). The third branch is a segment of the real axis between points $(-3, 0)$ and $(-4, 0)$; (Rule 6). The locus or path of points wherein the total phase of the vectors from the poles and zeros is $180 + n360$ deg is shown in Figure 4. The point of departure of the locus from the axis, i.e., where the system is critically damped, is just below the point H in the figure, the total phase at H being 180 deg (Rule 7).

Figure 5 gives a second example where

$$G(s) = \frac{K}{(2s + 1)(0.16s^2 + 0.64s + 1)} \tag{13}$$

The same procedure is applied, but two of the poles are complex $(-2 \pm j1.5)$ and the angle of departure of the locus from the poles is given by Rule 8. Here the departure angle from the pole $(s = -2 + j1.5)$ is plus 45 deg. since the contribution of the pole at $s = -0.5$ amounts to minus 135 deg and that of the conjugate pole to minus 90 deg (angle signs as in Figure 1).

How to interpret the locus

In any system, settling time (the time for system response to remain within 2 percent of its final value), the number of oscillations prior to reaching settling time, the peak overshoot, and the time to reach it, are all related to the *natural frequency* and the *relative damping* of the system.

These two quantities, expressed as constraints on the location of the roots, determine the vectors from the origin to the desired position of the two control poles. The control poles are the two complex roots nearest the imaginary axis that give rise to dominating terms in the transient response of the system. *Relative damping loci (ζ constant) are radial lines starting at the origin, making angles $\theta = \cos^{-1}\zeta$ with the negative direction of the real axis.* Natural *frequency loci are circles centered at the origin of* radius *equal to the natural frequency.*

When zero steady-state position error is specified, an open-loop pole is required at the origin, calling for zero steady-state velocity error in a system with a simple feedback link

$$\sum_{i=1}^{v} \frac{1}{P_i} - \sum_{i=1}^{u} \frac{1}{Z_i} = 0 \tag{14}$$

Having determined the desired location of the control poles, the next step is to locate the poles and zeros of fixed elements. Fixed elements are those like load, servomotors, plant, and other elements, over which the designer has no control, or at best is limited to a catalog selection.

Locus construction is eased by expressing all time constants as a ratio of one of them before inserting the corresponding poles and zeros on the diagram. A few phase lines for DVL (if it occurs) could be drawn at the same time. If data on fixed elements are not available, frequency response tests or correlation techniques may be necessary to obtain them.

Choice of compensation is governed by the degree of freedom available. The designer may be free to add any compensating network to the system, or may be limited to manipulation of a few parameters in a specific compensating network. In general, the designer of a servo system has more freedom than one working in the process control field where many frequency sensitive elements are part of the process.

Having provisionally decided on the type of compensation (lag, lead, cancellation), poles and zeros of the proposed compensating network are located on the diagram, asymptotes are estimated, and trial root loci are sketched in the regions of interest (the areas around the points determined by specifications). Adjustment of the positions of these poles and zeros, to make the locus pass through the points, is by trial and error. If this is impossible, then some other configuration must be tried.

When the locus finally passes through the desired points, the compensating poles and zeros are read off, and the network with the corresponding transfer function is specified. The value of gain required in the system is obtained by applying Equation 5.

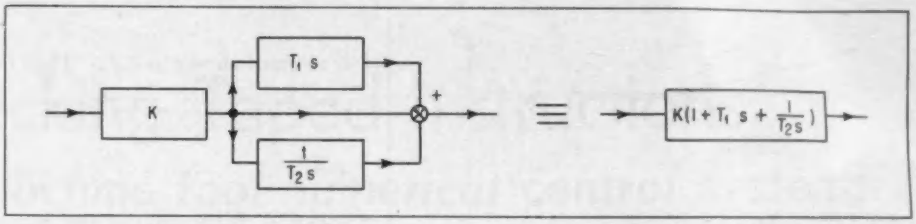


FIG. 6. The transfer function of a three-term controller, where T_1 is the derivative action time and T_2 the integral action time.

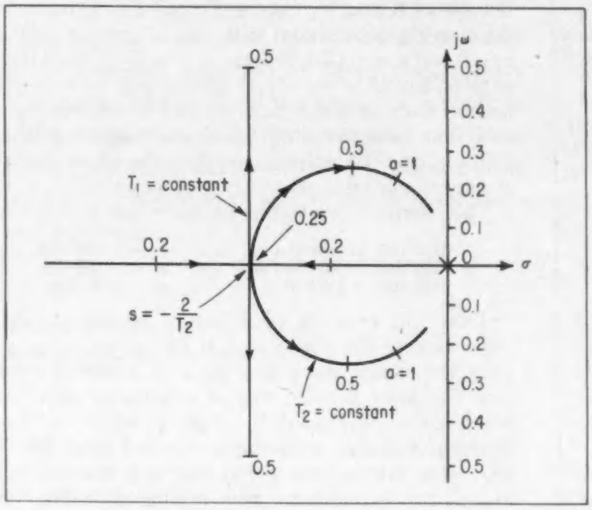


FIG. 7. When the ratio T_1/T_2 is greater than 0.25, the zeros contributed by the controller become complex. By maintaining T_1 or T_2 constant and varying a, the zeros lie on a line normal to the real axis intersecting at $s = -2/T_2$ or on a circle centered at $s = -1/T_2$ passing through the origin.

Root locus applied to three-term control

Linear compensation is usually effected in the process control field by a three-term process controller with adjustable parameters. The transfer function G(s) of a theoretical controller is

$$G(s) = K\left(1 + T_1 s + \frac{1}{T_2 s}\right) \tag{15}$$

where K is the gain (inverse of proportional band), T_1 is the derivative action time, and T_2 the integral action time. The block diagram of such a controller is shown in Figure 6. To determine the effect of the controller on the root locus of a system, G(s) is factored

$$G(s) = \frac{KT_1}{s}\left(s + \frac{1+\sqrt{1-4a}}{2T_1}\right)\left(s + \frac{1-\sqrt{1-4a}}{2T_1}\right) \tag{16}$$

where $a = T_1/T_2$

In a root-locus diagram, the controller contributes a first-order pole at the origin, two first-order zeros whose position is adjustable by varying the integral and derivative time settings, and a gain parameter on the locus. If a = 0.25, a frequently used setting, then there will be a second-order zero at $s = -\frac{1}{2T_1} = -\frac{2}{T_2}$

For higher values of a, zeros will be complex, as shown in Figure 7.

Actual process controllers contribute additional poles due to time constants of their components. These poles should be removed from the origin so that they will not appreciably affect the locus in significant areas. Some controllers also suffer from interaction between the terms. When interaction occurs, the area determined by the range of adjustment of T_1 and T_2 within which the controller zeroes can be manipulated is still more restricted. Thus an interacting controller requires a wider range of adjustment of its terms.

For example, in series-connected controllers the interaction due to integration of derivative response (or differentiation of the integral response), in addition to that of proportional response, results in modification of G(s) to

$$G(s) = K\left(1 + a + T_1 s + \frac{1}{T_2 s}\right) \tag{17}$$

where T_1, T_2 are action times when controllers are used as two-action controllers (i.e., P + D or P + I, but not P + D + I), and a is the ratio of the calibrated settings T_1 and T_2. Resolved into factors,

$$G(s) = \frac{KT_1}{s}\left(s + \frac{1}{T_1}\right)\left(s + \frac{1}{T_2}\right) \tag{18}$$

This means that zeros of these controllers are always real, and move along the real axis only.

As an example, consider a plant consisting of a first-order lag and a distance velocity lag which is to be controlled by a three-term noninteracting con-

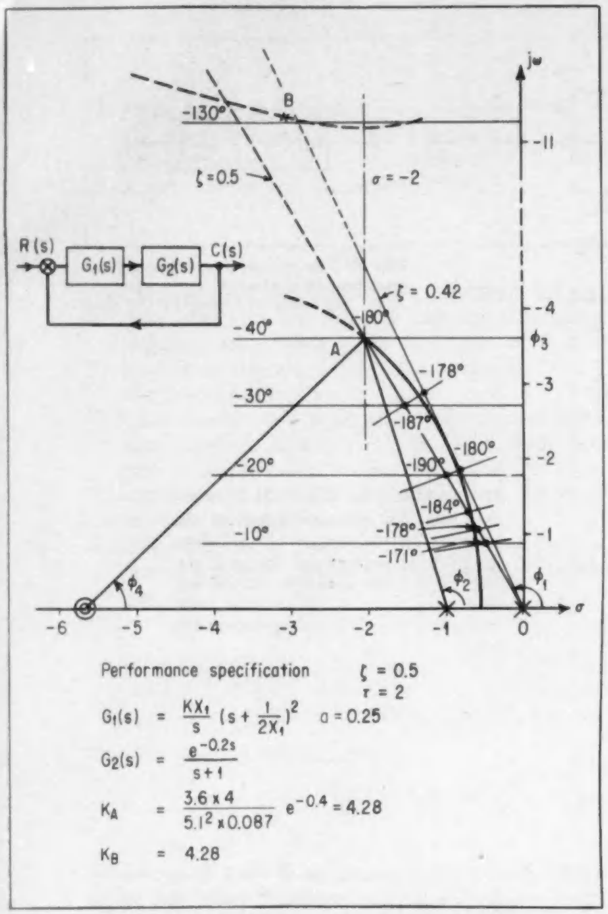


FIG. 8. With the relative damping and the system settling time known, the controller gain and time constant settings can be found from the root locus diagram. First the controller secondary zero must be found. The plant pole and controller pole are fixed from the specification. The control root A determined from the settling time must lie on the locus, with contributions from the poles and zeros totaling 180 deg. This gives the phase angle contributed by the controller zero as $\phi_4 = 43$ deg. Trial points evaluating the phase totals on the damping line and the controller pole vector for different values of ϕ_4 give the locus path.

troller of the type described above. It is desired to achieve a relative damping of 0.5 and a settling time of twice the first-order-lag time constant by a suitable adjustment of controller settings.

Only the upper part of the s plane will be considered, since no additional information is obtained from the lower part, the loci being symmetrical about the real axis. The first-order-lag time constant will be taken as a reference. The point corresponding to $\zeta = 0.5$ and $\tau = 2$ (where τ is the ratio of the settling time to the reference time constant) lies on a straight line making an angle of 60 deg ($= \cos^{-1} 0.5$) with the negative direction of the real axis at a distance of four units from the origin ($|s_n| = \frac{4}{\zeta\tau}$). This is the location of one of the required poles. Figure 8 shows the line and point A.

In the example, the DVL time constant is taken to be 0.2 of the reference and a for the controller is assumed chosen as 0.25. Then $G_2(s)$ of the plant

$$G_2(s) = \frac{e^{-0.2s}}{s+1} \tag{19}$$

and

$$G_1(s) = \frac{KX_1}{s}\left(s + \frac{1}{2X_1}\right)^2 \tag{20}$$

where X_1 is the ratio of the derivative time setting to the reference time constant. The problem is to determine K and X_1 (hence T_1 and T_2) in order to position the control root at A. $G_1(s)$ gives a pole at $s = 0$ and a second-order zero at $s = -1/2X_1$ which is to be found; while $G_2(s)$ gives a pole at $s = -1$ and a family of phase lines parallel to the real axis, each line corresponding to a phase lag of ($0.2\ \omega\ 180/\pi$) deg. The poles are marked, the phase line at A drawn, and total phase lag at A measured.

The contributions to this lag are found as follows:

that due to pole at $s =\ \ 0$ is $\phi_1 = -120$ deg
that due to pole at $s = -1$ is $\phi_2 = -106$ deg
that due to DVL is $\phi_3 = -40$ deg

Thus the required contribution of the second-order zero to the phase at A is ($\phi_1 + \phi_2 + \phi_3 - 180$) deg. Since the phase angle of a second-order zero (or pole) is twice that of a first-order zero (or pole) at the same point, the angle ϕ_4 which the line through A makes with the horizontal must be 43 deg. The intersection of this line with the real axis locates the second-order zero of the controller. A few trial points along the line $\zeta = 0.5$ show that the fundamental branch of the locus under consideration intersects the line again at a distance of 1.3 from the origin, but its departure from the line is not serious. A system adjusted to possess a root at A will simply become somewhat less damped as its gain decreases during operation, the lowest ζ having a value of about 0.42. If such decrease in stability cannot be tolerated, the controller second-order zero must be shifted towards the origin. This shift will, however, move the locus away from the point A with a resulting increase in settling time. The gain at A is found (using Equation 5) to be 4.28.

Due to DVL, the root locus possesses other branches which are not so significant. To insure that the absolute damping does not decrease, point B is calculated for the same gain value. Figure 8 shows that while it lies to the right of the specified damping line ($\zeta = 0.5$), the root on this branch is more heavily damped than that on the fundamental, and its effects will not significantly change response.

The settings found for the controller are then

T_1 = 0.087 times the reference time constant
T_2 = 0.348 times the reference time constant
K = 4.28 times the reference time constant

If a controller is incapable of providing such values of the parameters, values must be assumed which are in its range, and their effect noted on the locus.

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Checking Taped Instructions

for machine tool numerical control systems

One way to verify the control data recorded on a magnetic tape for a contouring system is to make a part. But if the tape has a fault, it will be reproduced on the part—and time and money will have been wasted. Here's a better way: check the tape automatically without even making a part.

VANCE ROGERS
Boeing Airplane Co., Wichita Div.

Under Air Force sponsorship, the Boeing-Wichita magnetic-tape service center produces machine tool control tapes for several Boeing divisions as well as for a group of other aircraft firms and suppliers. Among the latter are Lockheed, North American, Convair, Martin, Rohr, Rocketdyne, and Consolidated Machine Tool Corp. The work load at the center is considerable; the Wichita plant alone has ten numerically controlled machines: viz., three huge skin mills, three profile mills, and four riveting machines.

Soon after the tape center began operation, it became apparent that new diagnostic techniques were needed to expedite the preparation of usable magnetic tapes. In case of discrepancies, it was necessary to identify the specific segment of the numerical control system that was at fault. Was it the engineering drawing, the computer subroutines, the language, the specialized digital computer, or the magnetic tape? Was the final assembly of command information compatible with the response characteristics and other capabilities of the machine tool system? And was the command information sufficient and correct to permit the machine tool to produce the piece of hardware required by the engineering drawing? The diagnosis had, of course, to be made in the tape-preparation stage. It would have been extremely time-consuming and expensive to wait until the numerical control system produced a part not acceptable to Quality Control or failed to produce a part at all before looking for the source of trouble.

The system developed for this diagnostic purpose is the Boeing "verifier", which includes equipment for monitoring and printing the instructions recorded on magnetic tape by the Concord Controls—Giddings & Lewis director. The latter is a special-purpose digital computer designed to prepare control tapes for numerically controlled machine tools. The printed record of the verifier can be interpreted for direct comparison with the raw input data inserted into this computer. Completely separate from the director, the magnetic-tape verifier is capable of simulating the electronic control system of the machine tool and duplicating the recording characteristics of the specialized computer. The main unit in the verifier is a set of spare General Electric 3S7512 RP Series magnetic-tape contouring-control equipment. Interconnected with the electronic sections of the contouring control are six other subsystems, as follows:

1. a modified Ampex Model FR 114 tape transport mechanism
2. a 12-channel recording oscillograph, Eden Model 8204
3. a 12-channel oscilloscope, Rycom Model 2400
4. a conventional 4-watt audio amplifier and speaker
5. a record head and record amplifier installed in the tape transport mechanism
6. a square wave generator, Hewlett-Packard Model 211A

The flow chart, Figure 1, shows typical connections for the verification system. The chart is applicable to each motion track, the intermittent function tracks, and the reference track. Figure 2 is a general view of the verification equipment.

How the verifier works

The signals impressed on the 1-in. wide, 14-track Mylar tape by the recorder section of the director are essentially saturated square waves. However, the playback heads on the tape transport differentiate the recorded square waves so that they appear to the control system as alternate positive and negative pulses. The reference track carries a 12-ma saturated square wave at a frequency of 200 cps. The signals on each of the five motion tracks are also 12-ma saturated square waves, but their frequencies vary between 180 and 220 cps, depending upon the velocity and direction of motion required along the machine tool axis. The intermittent function commands are carried on six tracks and approximate 20-ma sine waves at 200 or 4,000 cps, or at 4,000 cps modulated by 200 cps. Two tape control tracks use 12-ma sine waves at 200 cps.

The preamplifiers, which are high-gain units with cathode followers, raise the low-level signals from the playback heads to between 80 and 120 volts for introduction into the circuitry electronics. The reference signals at a constant 200 cps are routed from the preamplifier to the diode-waveshaper, which delivers a sine wave in phase with the pulses received from the tape plus a cosine wave that is 90 deg out of phase. The synchro-exciter power amplifier transforms the input sine and cosine waves received from the diode waveshaper into balanced three-phase sine waves. In the machine tool servomechanism, this three-phase sine wave would be used to excite the position-measuring synchro control transformers in the feedback portion of the control loop. In the magnetic tape verifier, how-

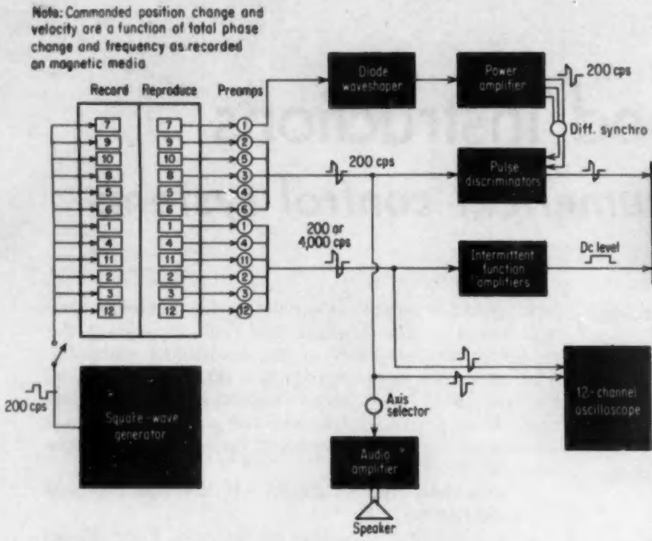
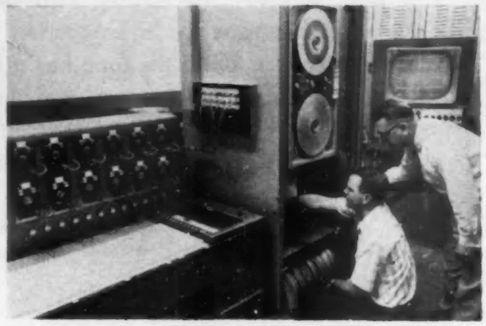


FIG. 1. Schematic diagram of tape verifier for Concord-G&L director.

FIG. 2.
View of verification equipment. Tape under test is being processed through magnetic-tape reader in center. Oscillograph is at left and oscilloscope at right.



ever, it is returned directly to the pulse discriminators for all of the motion axes.

The positive and negative pulses from the motion track for each axis are fed to their respective discriminators. Each discriminator panel normally receives feedback pulses representing tool position and compares them with the position-command signals from the motion track. The discriminator output, which is a dc voltage proportional to the phase difference, is delivered to the amplidyne field panels. In the verifier, the discriminator circuitry includes a 5692 electron tube connected essentially as a flip-flop with a left- and right-hand driver. Each driver is a 5691 tube; the left-hand driver receives the pulses from the motion channel while the right-hand element receives pulses from the reference channel. If the pulses occur exactly 180 deg apart, a balanced square wave is obtained. This is the salient principle of verification, as will be brought out later in this article.

The output signal from the 5692 is filtered and clipped and sent through a conventional cathode follower stage to a 6H6 tube, which is connected to an 0A3 tube. This combination limits the peak-to-peak voltage of the square waves to the voltage of the 0A3 reference tube. After additional filtering, this square wave is sent through a cathode follower. A shift from 0 to 360 deg in the phase relationship between the reference and command waves causes a linear swing in the discriminator dc output voltage from 0 to plus 44 volts, then to minus 44 volts, and back to 0 volts. The abrupt change from the maximum positive dc level to the maximum negative dc level at the output of the discriminator occurs at 180 deg phase shift. In the verifier, the polarity of the voltage is used to indicate whether positive or negative motion is being called for by the command signals.

The diagrams in Figure 3 show typical discriminator voltage patterns for various amounts of phase difference between the reference and motion commands:

Figure 3A—Represents the output of the discriminator when the motion commands and reference commands are in phase or when no motion is requested.

Figure 3B—Typical of motion and reference signals 90 deg out of phase.

Figure 3C—Motion and reference signals 179 deg out of phase (this is just prior to the abrupt change from maximum positive voltage to maximum negative voltage, which occurs at 180 deg phase shift).

Figure 3D—Motion and reference signals 181 deg out of phase (note polarity change).

Figure 3E—Motion and reference signals 270 deg out of phase (note the return toward zero volts as the phase change comes nearer to 360 deg).

Figure 3F—Motion and reference signals again at the in-phase condition, having completed a change of 360 deg.

The synchro transformer that provides the feedback signal from the machine tool is normally connected through precision gearing, so that 0.1 in. of motion of the machine slide produces a full 360 deg rotation of the synchro rotor; or 3.6 deg synchro rotation is equivalent to 0.001 in. of machine motion. Similarly, each full cycle of voltage fluctuation recorded by the oscillograph is indicative of 360 deg phase change or 0.1 in. of programmed motion. Thus, by adding the number of whole cycles recorded and by interpolation of the amplitude of portions of cycles, the commanded distance and velocity can be closely approximated.

The recording oscillograph reveals all motion commands as streams of alternate positive and negative voltage spikes. The polarity of the spikes of greater magnitude show direction; the number of the spikes in any given interval of time is proportional to the commanded velocity. When no motion is required, the recorded trace is a straight line having the same voltage level as

that developed by the last motion command. This voltage is zero, if the distance of the preceding motion was a whole-number multiple of the basic 0.1-in. increment. If the distance was a mixed-number multiple of 0.1 in., the recorded voltage will be of a magnitude proportional to the fractional part of the distance. The intermittent function commands, such as coolant-on, coolant-off, planned stop, playback stop, and the clamping or inactivation of any motion track, are recorded on the oscillograph record as dc voltages with ac components. Thus the presence of such commands on the tape is signaled by a broad trace, their absence by a line trace.

The signal from the reference track is essential to the functioning of the discriminators; a failure or drop-out of this signal causes loss of the traces being recorded for all motion tracks. A failure in an intermittent function track affects only the particular oscillograph track assigned to this function. Because of the greater time constants within the intermittent-function circuitry of the machine tool control, larger fault magnitudes can be tolerated in this track than in the motion tracks. A loss of signal in any motion track is indicated by discontinuity of the oscillograph trace for the machine axis concerned; it does not affect the other traces.

The multichannel oscilloscope in the verifier provides a visual analysis of the quality of the signals recorded on the magnetic tape. The audio amplifier and speaker also perform a monitoring function, giving an audible interpretation of the magnetic signals. Certain sounds are characteristic of specific faults, so that the verifier operator need not keep constant watch on the multichannel oscillograph. The oscillograph, oscilloscope, and audio amplifier are interconnected into the verifier circuitry so that each is capable of selectively monitoring any track recorded on the magnetic tape. This flexibility has proven to be of great value in analyzing suspected faults in the recorded commands or in the tape itself.

The extra record head and the signal generator make it possible to impress upon the magnetic tape information signals having the same characteristics as those delivered by the director. This facility makes available a means for checking a tape splice. A signal is recorded and then almost immediately played back through the verifier system to permit evaluation of the splice or the quality of used tape.

This verification system thus provides all elements necessary for analysis of a magnetic tape program generated for the electronic circuitry of a 200-cycle phase-analog servomechanism. In addition, it permits a quality control analysis of the magnetic tape itself. The system is equally as sensitive to faults and errors as is the final controlled element; for example, a human hair passed between the magnetic tape and the playback head is revealed as a system failure on the three monitoring devices.

Detectable faults

The permanent, printed record from the oscillograph yields an uninterrupted commentary of all instructions on the magnetic tape for a particular numerical-control program. This printed record can be correlated with the input data to the specialized computer with respect to sequence, time, distance, direction, and speed of all motion commands and auxiliary function commands. The following are some of the faults detectable by the verifier, anyone of which could prevent the production of a usable part:

1. Magnetic oxide missing from new tape.
2. Wrinkles or corrugations on tape.
3. Presence of excessively strong test signal on new tape.
4. Improperly degaussed reused tape.
5. Flaking of coating on metal leaders, causing shorting of recorded signals and excessive build-up on the reading head.
6. Loss of magnetic oxide due to repeated use of production tape or physical damage.
7. Contamination of tape by metallic dust and foreign particles encountered in the machine environment.
8. Contamination of tape by mist lubricant and coolant vapors.
9. Sign errors occurring in the specialized computer and not previously observed by its operator.
10. Omission of any intermittent-function signal from the magnetic tape.
11. Variations in signal strength caused by oscillations of tension arms in the recorder of the director.
12. Physical tape damage caused by "snaking" of tape through recording unit.
13. Erratic speed of tape across record head.
14. Variations of signal level impressed upon the magnetic tape.
15. Excessive acceleration and deceleration commands.
16. Omission of exponential time insertion to accommodate the dynamic response of the final controlled element.
17. Faulty magnetic tape splices.
18. Holes 0.001 in. or larger in recorded tracks on the tape.

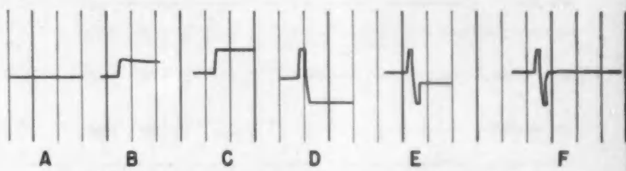


FIG. 3. Characteristic pulses resulting from varying amounts of phase difference between reference and motion signals.

Most of the above faults will preclude the release of a tape from the tape center. Therefore, the oscillograph recording that accompanies the programmed magnetic tape will not usually show malfunctions, except those caused by the computer and parts programmers at the originating company. However, it may be desirable to analyze the recording for: (1) proper programming of auxiliary functions, (2) amount of movement in any axis, (3) correct use of exponential time insertions for accelerations and decelerations, (4) existence of reversals of direction without proper exponential time insertions, and (5) sequence of the operation as programmed.

The accompanying table lists five sample portions of a numerical control program designed to demonstrate the effectiveness of the verification techniques. This program was punched onto paper tape (off-line from

the computer), which serves as the input medium for the machine tool director. The magnetic tape produced by the latter was processed by the verification system. Figure 4 shows the oscillographic record that resulted.

The meaning of the code on the manuscript is as follows:

X05—Sets the director to use all five axes.

X04—Sets director to record at 1:4 ratio. Director tape transport will move the tape past the record head at 3¾ ips, and the director processes are slowed to ¼ of normal.

X79—Sets the director to record a 200-cps signal on track 4 and all motion channels in use for a period of four sec. This is for a playback stop at the machine tool.

X09—Sets director to record a 200-cps signal on all motion channels and on track 11 for four sec. This is for planned stop at the machine tape transport.

X11—Sets the director to record a 200-cps signal on track 1, which will energize the coolant solenoid on the machine tool.

00+—Sets director to record motion commands to move, in ½ sec, the distance indicated in columns to the right.

001, 002—Same as 00+ but time is 1 sec, 2 sec, etc.

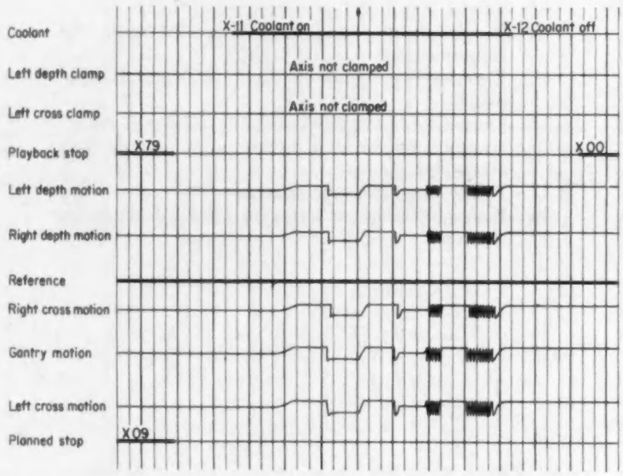
X12—Sets director to cease recording 200 cps on track 1. Coolant solenoid will be de-energized at machine.

X46—Sets the director to record motion signals on right head cross, right head depth, and gantry (three out of five axis motions).

"Exponential time insertion" is actually a stretching of time in that it is required to accommodate the dynamic responses of the machine tool system during accelerations and decelerations. The changes in velocity are not instantaneous but are gradual and generally are achieved in approximately 2.5 sec.

FIG. 4. Five Examples Show Magnetic Tape Verification Technique

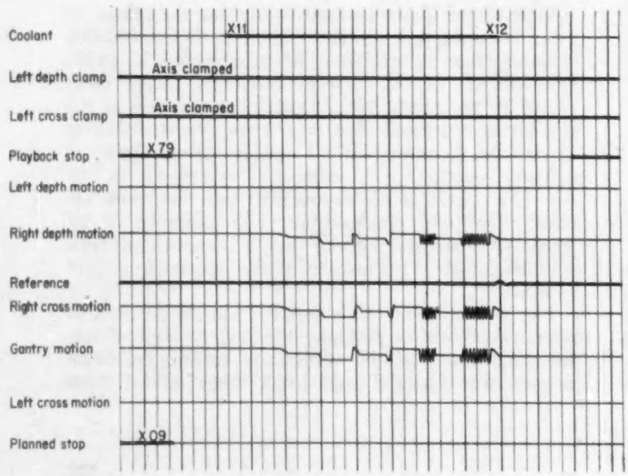
In all cases, oscillograph chart speed is 10 mm/sec. Note exponential time insertion in each example. Gantry clamp channel not shown.



EXAMPLE NO. 1

1. It is apparent that all commanded motion is in the positive direction.
2. All axis motions involve the same distances at like velocities.
3. The last command is for a motion of 1 in. Therefore, there are ten spikes, each representing a 0.1 in. increment.
4. The time delay between each command and the velocity of machine motion are easily determined from the known oscillograph chart speed.

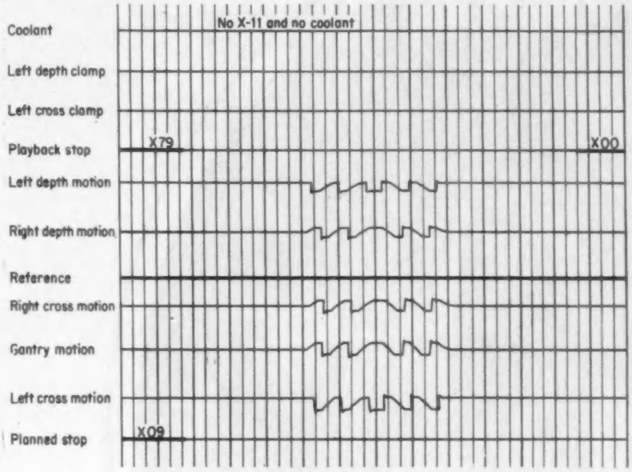
x05					
x04					
x79					
x09					
002	+0000000	+0000000	+0000000	+0000000	+0000000
x11					
00+	+0000250	+0000250	+0000250	+0000250	+0000000
002	+0000000	+0000000	+0000000	+0000000	+0000250
00+	+0000490	+0000490	+0000490	+0000490	+0000490
002	+0000000	+0000000	+0000000	+0000000	+0000000
00+	+0000550	+0000550	+0000550	+0000550	+0000550
002	+0000000	+0000000	+0000000	+0000000	+0000000
00+	+0000750	+0000750	+0000750	+0000750	+0000750
002	+0000000	+0000000	+0000000	+0000000	+0000000
001	+0006260	+0006260	+0006260	+0006260	+0006260
002	+0000000	+0000000	+0000000	+0000000	+0000000
002	+0010000	+0010000	+0010000	+0010000	+0010000
x12					
00+	+0000000	+0000000	+0000000	+0000000	+0000000
x00					



EXAMPLE NO. 2

1. This is identical to Example No. 1, except that all commanded direction is negative. Note abrupt reversal of spike.
2. Left depth and left cross motions are inactive.

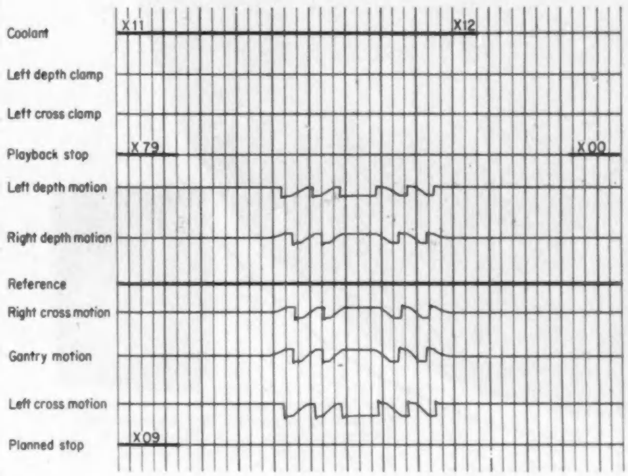
x46			
x04			
x79			
x09			
002	−0000000	−0000000	−0000000
x11			
00+	−0000250	−0000250	−0000250
002	−0000000	−0000000	−0000000
00+	−0000490	−0000490	−0000490
002	−0000000	−0000000	−0000000
00+	−0000550	−0000550	−0000550
002	−0000000	−0000000	−0000000
00+	−0000750	−0000750	−0000750
002	−0000000	−0000000	−0000000
001	−0006260	−0006260	−0006260
002	−0000000	−0000000	−0000000
002	−0010000	−0010000	−0010000
x12			
00+	−0000000	−0000000	−0000000
x00			



EXAMPLE NO. 3

1. Does not request activation of coolant pump. Note absence of broad trace.
2. Calls for a motion of 0.2500 in. first in the positive and then in the negative direction.

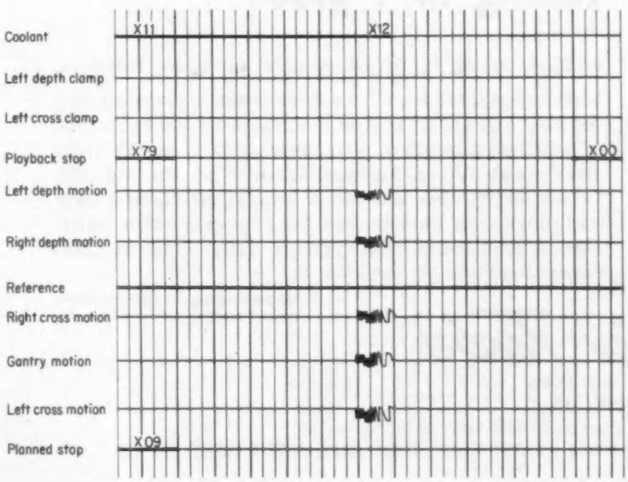
x05					
x04					
x79					
x09					
002	+0000000	+0000000	+0000000	+0000000	+0000000
005	+0002500	+0002500	+0002500	+0002500	+0002500
005	−0002500	−0002500	−0002500	−0002500	−0002500
x12					
00+	+0000000	+0000000	+0000000	+0000000	+0000000
x00					



EXAMPLE NO. 4

1. This is identical to Example No. 3, except for the expotential time insertion for acceleration and deceleration.

x05					
x04					
079					
x09					
x11					
002	p0000000	+0000000	+0000000	+0000000	+0000000
005	p0002500	+0002500	+0002500	+0002500	+0002500
005	m0002500	−0002500	−0002500	−0002500	−0002500
00+	+0000000	+0000000	+0000000	+0000000	+0000000
x12					
00+	+0000000	+0000000	+0000000	+0000000	+0000000
x00					



EXAMPLE NO. 5

1. This calls for an acceleration to 119.995 in./min in the positive direction, followed by an abrupt reversal to like speed in the negative direction.
2. Note that there are no exponential time insertions during acceleration, deceleration, or reversal of direction.

x05					
x04					
x79					
x09					
x11					
00+	+0000000	+0000000	+0000000	+0000000	+0000000
00+	+0009995	+0009995	+0009995	+0009995	+0009995
00+	−0009995	−0009995	−0009995	−0009995	−0009995
x12					
x00					

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Computer Analogs for Common Nonlinearities

CHESTER L. DUNSMORE, Van Nuys, Calif.

Analog computer circuits for four basic nonlinearities are presented, with some practical hints for their use, plus five more complex nonlinearities that can be simulated as combinations of the basic ones. The last circuit (for analoging stiction) gives a clue to why large analog computers are so often needed to simulate even relatively simple engineering problems.

BASIC NONLINEARITIES

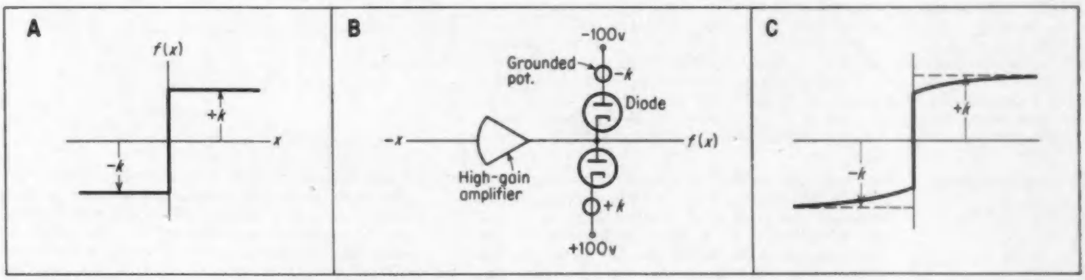


FIG. 1. BANG-BANG. The simple function of some variable x shown in (A) represents the response of an ideal relay (or the mathematical function sign x = ± 1). For the relay function +k need not equal −k. This function can be simulated on an analog computer by a high-gain amplifier and a pair of diodes, as in (B), in which potentiometers set the positive and negative values. But the transfer function of this circuit has a soft limiting characteristic (C) due to the space-charge nonlinearity of the thermionic diodes. Note that signal inversion by amplifiers must be observed in this and all succeeding diagrams.

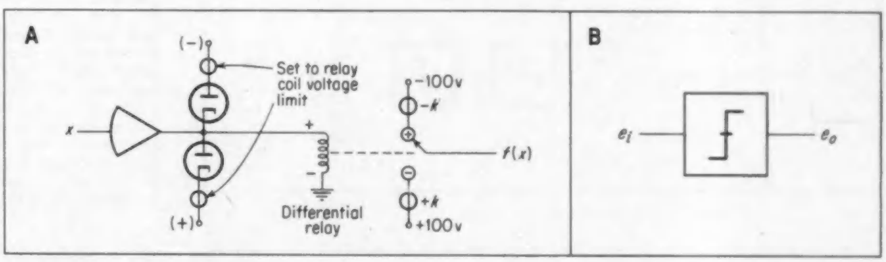


FIG. 2. BETTER BANG-BANG. The circuit in (A) adds a sensitive differential relay to the circuit of Figure 1B. In this case, the diodes are connected to limit the voltage applied to the relay coil to safe values. The function amplitude potentiometers are connected to the relay contacts to produce signal inversion or not, as desired. In these diagrams the relay contact marked + is closed when the amplifier output is positive, and vice versa. This circuit is represented in following figures by the symbol in (B).

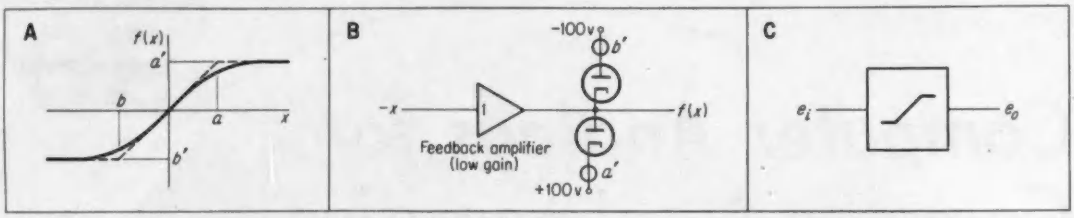


FIG. 3. SATURATION LIMITING. This function (A) can be simulated (B) by substituting an operational amplifier with a fixed low gain for the high gain amplifier in Figure 1B. Note that the diode characteristic again produces rounded corners on the function—generally all right in this case, since most physical systems "saturate" gradually. (C) is a schematic symbol for the saturation limiting circuit in (B).

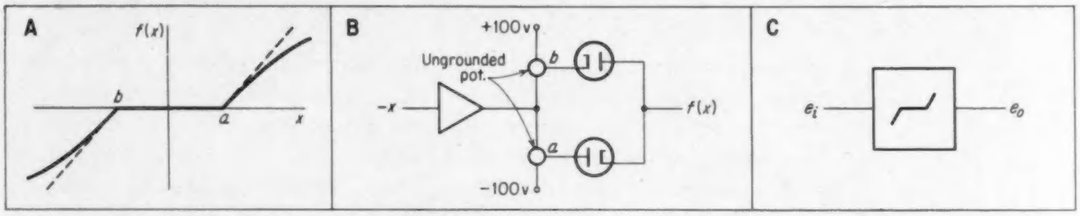


FIG. 4. DEAD ZONE. Many physical systems have a "dead zone", or threshold values below which an input signal produces no output. This function is illustrated in (A) and can be simulated by the circuit in (B). Again note the droop due to diode characteristics. This droop can be eliminated bv considerably complicating the circuitry. (C) is the symbol used in this article for the dead zone circuit.

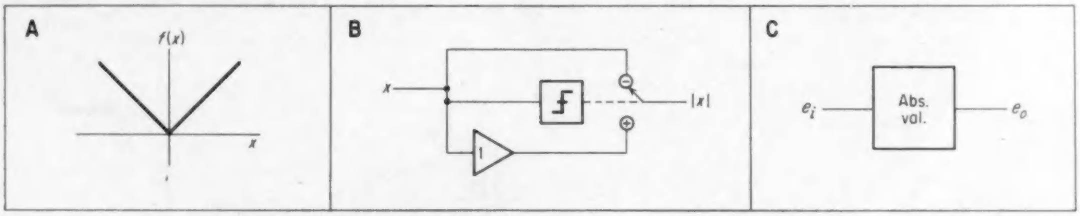


FIG. 5. ABSOLUTE VALUE. The function in (A) represents the positive or absolute value of x and can be simulated by a slight modification of the bang-bang circuit in Figure 2B. (B) shows that an extra amplifier is necessary and that the relay contacts are connected to carry the input signal forward unchanged when it is positive and inverted (positive output) when it is negative. (The bang-bang function can be produced simultaneously by this circuit by connecting the second pole of a 2-pole double-throw relay to potentiometers as shown in Figure 2B. This combination is used in **Figure 10.**)

COMBINED NONLINEARITIES

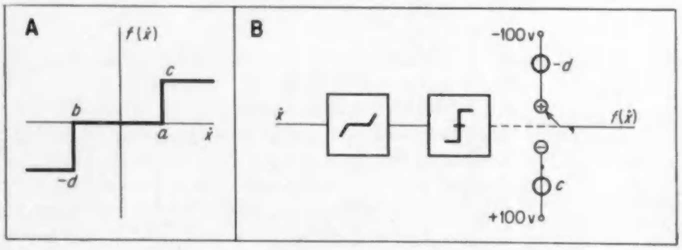


FIG. 6. COULOMB FRICTION. This function (A) is easily simulated by combining the dead-zone circuit with the bang-bang of Figure 2B. The bang-bang amplifier gain should be high enough to pull in its relay as low as possible on the slope of the dead-zone circuit output without operating spuriously in the dead zone. (NOTE: Differential relays have a zero-center position in which they make neither contact in the dead zone between their positive and negative pull-in currents.) Relay sensitivity is generally adjustable, and a low sensitivity or wide relay dead zone simplifies adjustment of the bang-bang amplifier gain.

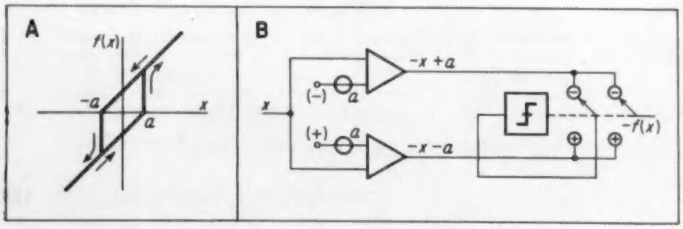


FIG. 7. NEGATIVE DEFICIENCY (OVERLAP). This is a somewhat simple form of hysteresis that can occur only about the origin. It is exhibited in hydraulic valves when the corners are lapped to provide positive feedback for very small fluid flows. The switching from one curve to the other depends on the relative values of input and output. This circuit can be in error when first turned on for values of the input variable smaller than a.

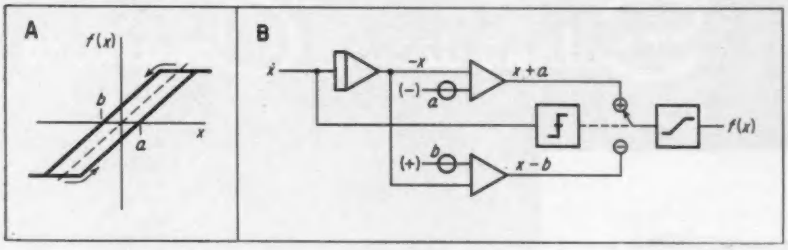
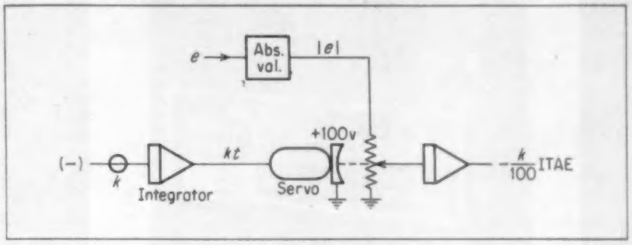


FIG. 8. HYSTERESIS (BACKLASH). This non-tracing function is encountered in almost any kind of system. Note that a and b may be both positive or both negative if desired. The side of the loop traced is determined by the polarity of the rate of change of the input variable, i.e., $\dot{x}$.

$$\text{ITAE} = \int_0^\infty t\,|e|\,dt$$

FIG. 9. ITAE. This criterion of servo performance (the integral of the product of time and the absolute value of error) involves the absolute value nonlinearity plus a multiplication of two variables. It can be simulated by using the absolute value circuit of Figure 5B with two integrators and a servo-driven potentiometer multiplier.



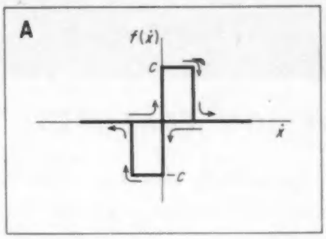
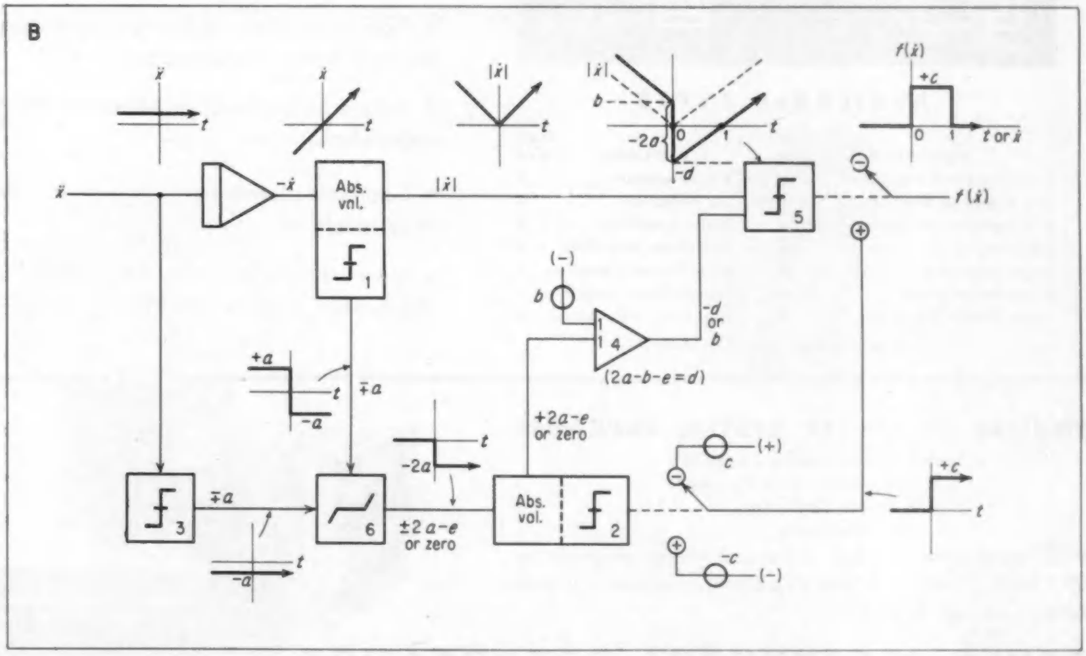


FIG. 10. STICTION (BREAKAWAY FRICTION). This simple appearing function (A) is a real equipment hog. The circuit in (B) takes 1 integrator, 8 amplifiers, 17 potentiometers, 10 diodes, and 4 relays when fully connected. Operation of this circuit can be understood from the waveforms (shown for a constant positive acceleration, with zero time defined when $\dot{x}$ goes through zero). Bang-bang 5 is switched by a change in polarity of the sum of $|\dot{x}|$ and the output of amplifier 4; that is, at $t = 0$ and again at $t = 1$. Note that absolute value and bang-bang functions are combined in blocks 1 and 2 as explained in Figure 5. Once the limit value, a, of bang-bangs 1 and 3 has been set, potentiometer b controls the time $t_1 - t_0$ for bang-bang 5 to reset. The circuit works the same way for a negative input, except that bang-bang 2 will select a negative output.



The Digital Valve Actuator
—A Brand New Approach

When and if the digital computer takes over the chores of process control, on more than an experimental basis, at least one valve actuator will be ready and waiting for direct digital control. Till then, this same actuator, combined with an inexpensive servo-driven commutator, should find wide application in many of today's analog electronic process control systems.

J. WAPNER & G. HOUPT
Fischer & Porter Co.

Past approaches to the problem of electrical valve actuation have been many and varied. Basically, they include: an electric-to-pneumatic converter, driving a standard pneumatic valve; a geared-down servomotor, operating from a standard feedback loop; an electro-vapor type, operating on thermal pressure; a self-contained electrohydraulic system; and a clutching mechanism on a continuously rotating motor. Each has its own advantages and limitations.

In the development of the digital valve actuator described below, two criteria guided the design effort—universal applicability and competitive price. How close the final design comes to achieving these aims remains to be seen.

Essentially a large stepping motor, the digital valve actuator consists of a toothed rotor with threaded bore, a threaded output shaft, 12 solenoids or operating coils, a two-piece cast housing, and a mounting means designed for use with any type of valve body. Figure 1 shows the complete actuator mounted on a standard two-inch valve. The exploded view, Figure 2, illustrates its major components. For simplicity rotor and shaft are shown as an assembly.

How It Works

Figure 3 shows the coil arrangement relative to the toothed rotor. The coils operate as three separate phases, each phase consisting of four parallel connected coils—two lower coils, 180 deg apart, and two upper coils directly above these. Phases are numbered 1, 2, and 3. There are 18 equally-spaced teeth in the rotor. When the coils of any one phase are operated, their magnetic fields tend to pull into alignment the nearest rotor teeth. The rotor in Figure 3, for example, is shown in the position it would assume if the phase-1 coils were energized.

Note the angular displacement of the phase coils. With this arrangement, sequential operation of the

Simple design—rugged construction

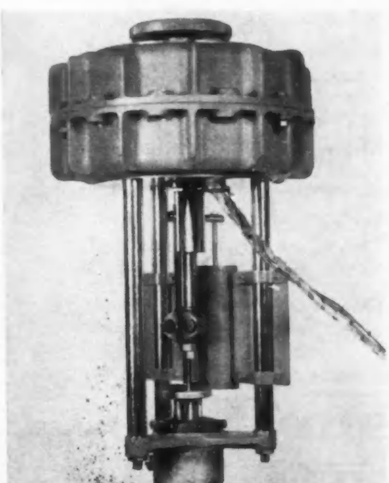
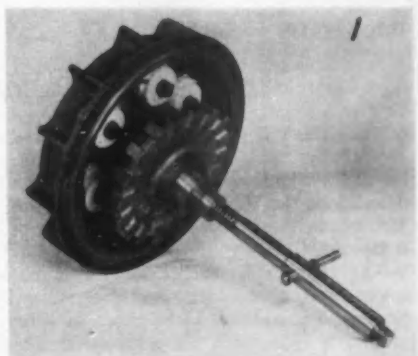


FIG. 1. Actuator mounted on a standard 2-in. valve.



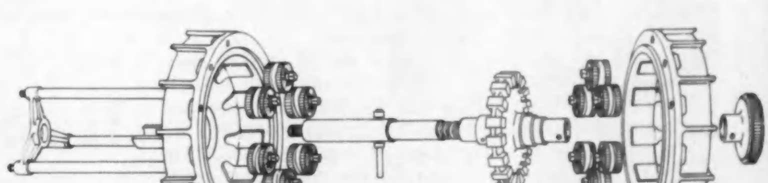


FIG. 2. Exploded view showing its clean internal construction.

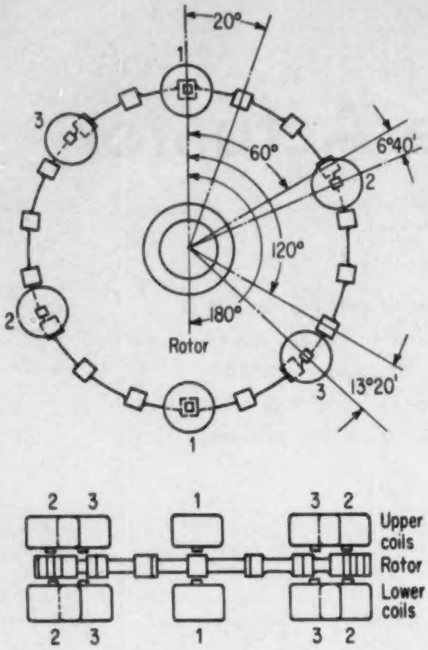


FIG. 3. Coil-rotor relationship for a single position of the rotor.

three phases produces a continuous stepwise rotation of the rotor, each step being equal to ⅓ of the tooth spacing. Since there are 18 teeth on the rotor, one complete revolution consists of 54 discrete steps. In practice, operation of the phase coils is overlapped. This simple refinement doubles the number of discrete steps per revolution. Direction of rotation depends solely on the sequence in which the coils are energized.

As the rotor turns, the output shaft moves up or down, depending on the direction of rotation. A roller guide attached to the lower housing prevents this shaft from turning with the rotor. With overlapped coil operation each step of the rotor produces less than 0.002 in. travel of the shaft.

Three Modes of Control

Several control techniques have been devised for both open- and- closed-loop operation. The circuit in Figure 4 illustrates a typical open-loop control using digital pulses. An electronic, bi-directional ring counter accepts the input pulse and sequences the operation of the coils. The number and direction of these pulses determines the valve position. With this system, the process itself serves as the feedback loops to a digital computer.

The immediate market for the actuator, however, is not in computer-controlled processes. Today's practical applications would be those in which the device acts as a servo, i.e., has its own feedback loop and operates in either direction from an analog difference signal. Two methods of closed-loop control have been developed for this type of application.

The first method requires the use of separate magnetic commutators mounted on the valve and separate transistorized control circuits for both clockwise and counter-clockwise operation. Although workable, this system has several drawbacks. It requires extensive circuitry and large heat sinks for the continuous on-off operation of the power transistors, and its cost is still relatively high. For these reasons details of its operation have been omitted.

The second method, one which is presently practical, is to use a commutator driven by an inexpensive servomotor, as shown schematically in Figure 5. A small permanent magnet attached to the commutator shaft sequentially operates the mercury-wetted power contacts. These contacts permit operation at high currents and voltages, without introducing a heating problem. Arc-suppression diodes and capacitors provide sufficient protection for the contacts. This type of operation also includes a feedback loop in series with the input signal. The servomotor, pictured in Figure 6 with its control circuit, operates in either direction, depending on the difference signal.

Performance

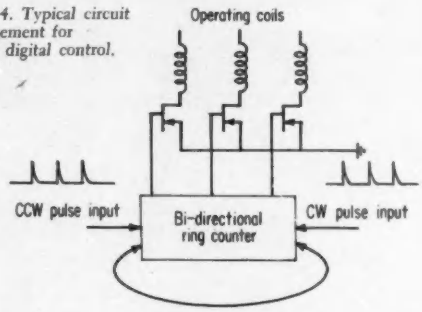
The actuator produces a minimum power of 110 lb-in. per sec. With a lead screw pitch of 0.2 in. per rev, and a shaft speed of 0.2 in. per sec, output thrust is 500 lb. The unit requires an input of about 160 watts while running and 40 watts at standstill.

In the event of a power failure, the handwheel permits manual positioning of the valve stem.

Lead screw used is of the recirculating ball bearing type and has a life of about 6 million operating cycles at full load.

Input signals may be digital or analog

FIG. 4. Typical circuit arrangement for direct digital control.



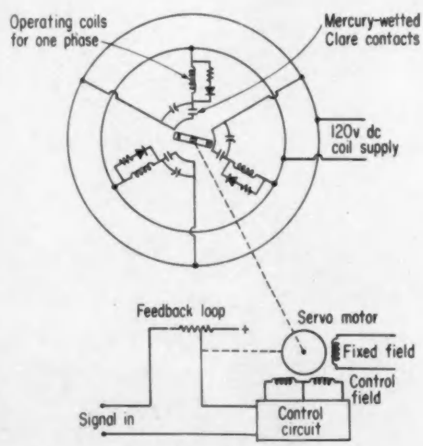


FIG. 5. Servo-driven commutator circuit used with analog inputs.

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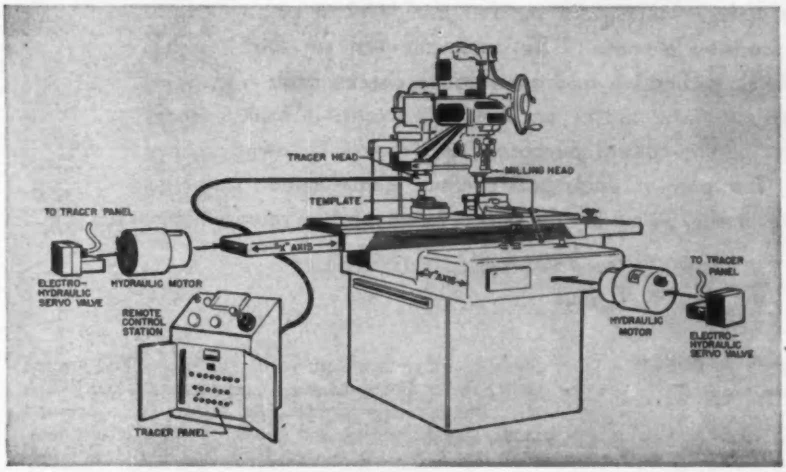

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H First in Control

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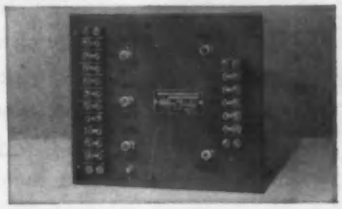
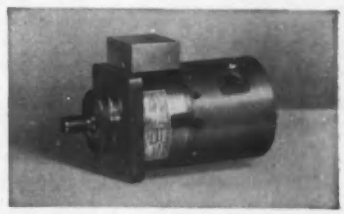


Transistorized servo amplifiers—proportional and integrating low voltage amplifiers designed for servo systems, incorporating servo valves, d-c relay and servo motors.

Feedback transducers—industrialized linear and rotary transducers providing accurate sensing and feedback for servo loops.



Hydraulic motors—roll-vane motors producing high torques at low speeds. Often connected directly to load. Integral tachometer optional.

Servo accessories—input commands, meters, manifolds, phase conversion panels, consoles, etc., to complement the servo control systems.

CIRCLE 115 ON READER SERVICE CARD

Automatic System Checks Automotive Voltage Regulators

Automotive voltage regulators require 100-percent production-line inspection. One company producing 9,000 regulators a day and using conventional checking procedures required a minimum of six to eight highly skilled workers to handle the inspection load, and even then inspection consistency was not satisfactory. Technical and economic studies showed that the checking procedure could be done automatically, thereby reducing the number and level of personnel and removing the human decision element. The automatic test set that resulted from these studies makes qualitative and quantitative checks, seals and dates the regulator if acceptable and marks on it what's wrong if faulty, prints out the test results for quality-control purposes, and checks its own circuitry at regular intervals. The plug-in packaged-function construction simplifies maintenance and makes it easy to modify the system to meet future requirements.

OSCAR A. DAHMS, JR., and CHARLES H. BOBICH
Chicago Div., American Bosch Arma Corp.

Conventional 100-percent inspection of voltage regulators requires competent inspectors well-trained in the use of production-line test instrumentation, capable of reading meters accurately, and able to make borderline judgments on questionable units. Each operator must also make quantitative and qualitative electrical measurements, seal and date acceptable regulators, and mark the type and amount of rework necessary on failed or out-of-tolerance units. The difficulty and high cost of a satisfactory manual inspection program, coupled with the competitive nature of the voltage regulator market, prompted a study of the possibility of making the inspection operation automatic. The result was the building of a flexible system that would do the following:

1. directly measure voltage regulation, current limitation, and point of cut-in operation
2. qualitatively check voltage fluctuation, series voltage (*IR*) drop, and reverse current operation on a go/no-go basis.
3. date stamp and warranty-seal acceptable units, mark the type of failure on unacceptable ones, and print out a complete inspection record.

A LOOK AT THE SYSTEM

A complete automatic test set, consisting of a central control console, test-fixture module, and data recorder is shown in Figure 1. The control console is the heart of the system and houses the power module, self-check module, and test measurement modules. This overall unit handles the functions of programming (including selection of test parameters and test limits), measurement, and calibration and checking of the test system. Indicator lights on the front panels of the measurement modules visually identify test limits and test results. Counters report the total number of test cycles and the total number of regulators that have been rejected during these cycles.

Remotely located at the end of the production lines, but electrically connected to the other parts of the system, are the test fixture modules—the control stations for actuation of the test system, for date-stamping and warranty-sealing of acceptable units, and for marking failed or out-of-tolerance units. Since the central control console module contains three measurement modules, three inspection stations can be used simultaneously. Cable lengths of up to 30 ft between the test stations and the control console mean that the system elements can be widely separated. The data recorder is a standard Flexowriter.

A complete test cycle consists of: 1) insertion of a regulator into the pneumatically-clamped test fixture, 2) automatic programming of the test sequence, 3) automatic measurement of test parameters, 4) periodic self-checking and calibration of the system, 5) marking of units, 6) print-out of data, 7) reset of system.

WHAT ARE THE ECONOMICS?

It used to take an inspector 18 to 20 sec to inspect and test each regulator, not including the time required to mark the type of fault on each rejected regulator or to calibrate the test instrumentation.

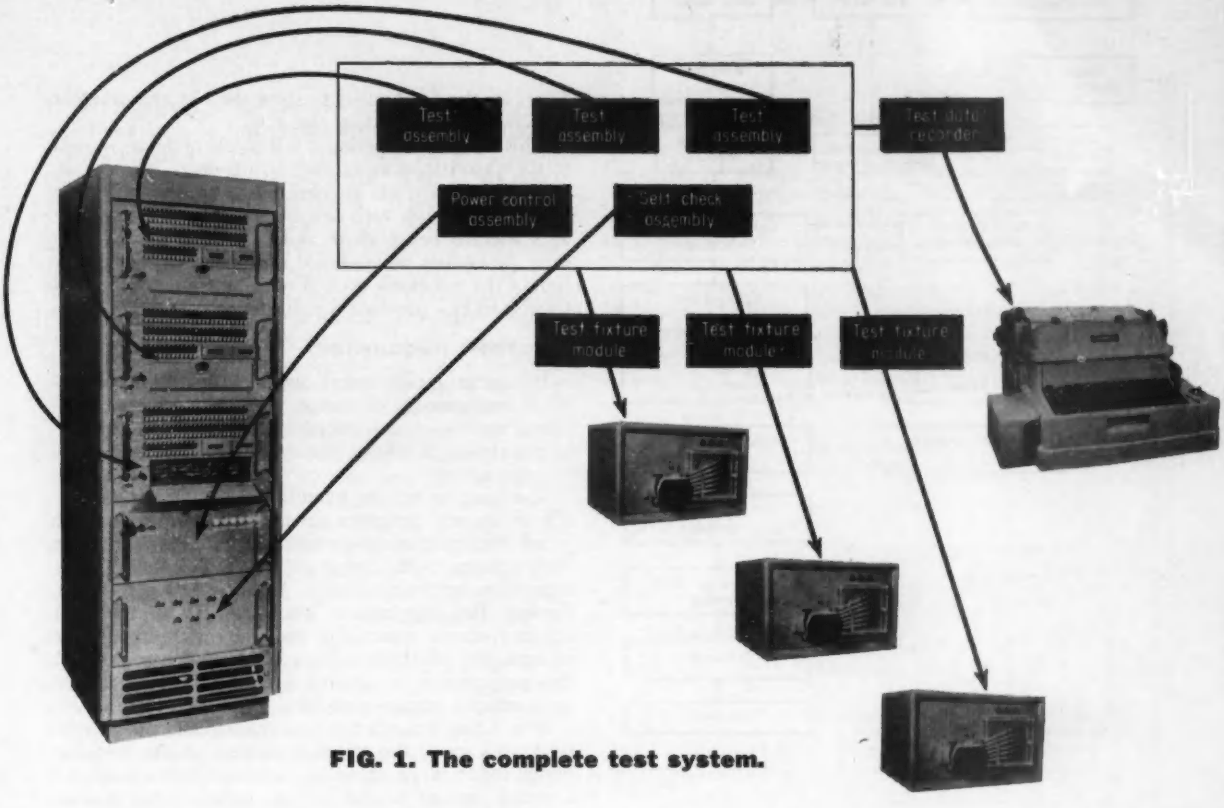


FIG. 1. The complete test system.

In contrast, the automatic test set takes only 4.8 sec to run through the complete inspection sequence for each regulator, a reduction of 75 percent over optimum manual operation. And there are many auxiliary and intangible gains: production flows more smoothly, there are fewer pile-ups of regulators, the number and skill level of inspectors are reduced, delivery schedules and customer confidence in the product line are improved, and there are fewer field failures. In addition automatic recording and marking of reason for rejection speeds reworking, permits closer supervision of trouble spots by correlating rejected regulators with the worker who adjusted the unit prior to final inspection, gives all the data necessary for a careful analysis of the production process and quality control procedures, and, finally, practically eliminates calibration time.

TEST SYSTEM DESIGN AND OPERATION

With respect to functional design and operation, the major areas of the automatic test set are programming, self-check and calibration, parameter measurement, and test-limit setting. The mechanical and electrical problems of designing for simplified maintenance and for flexibility are achieved primarily through the use of functional modular construction.

Programming

Test-sequence programming consists primarily of connecting test circuits or comparison devices in the measurement section of the test set to a specific circuit in the unit undergoing test. The programmer in this case is a 25-position stepping switch, which starts from a switch closure when a regulator is inserted in the test fixture. The switching rate is five steps per sec, determined by a transistor-controlled oscillator. As the programmer steps, other control steppers are actuated at specific intervals to carry out the functions of measurement, self-check and calibration, marking, printing, etc., in the test set.

The programmer selects a set of conditions, which, when satisfied, cause the program stepper to initiate the next sequence. For instance, when voltages and currents are matched during the voltage regulation and current limitation tests, a signal passes through a limit

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CAN YOUR PRODUCT BE INSPECTED AUTOMATICALLY?

The system described here was specifically designed for inspecting voltage regulators, but it suggests the possibility of similar equipment for inspecting the products flowing from many industrial production lines. And it seems to be economically feasible and technically desirable to automatically inspect many items that, as of now, can't be produced automatically. Look at your assembly line and see if automatic testing and inspection won't save money and headaches.

A fund of techniques (see "The Functions of Guided Missile Checkout Systems", CtE, April '58, p. 98) and equipment (see "Five Examples Show Versatility of Automatic Testing Systems", CtE, August '58, p. 81) have been built up as a result of military experience and demands. In fact, the knowhow in the designing of this voltage regulator testing system resulted from experience on military checkout systems, such as for testing inertial guidance computers.

—Editor

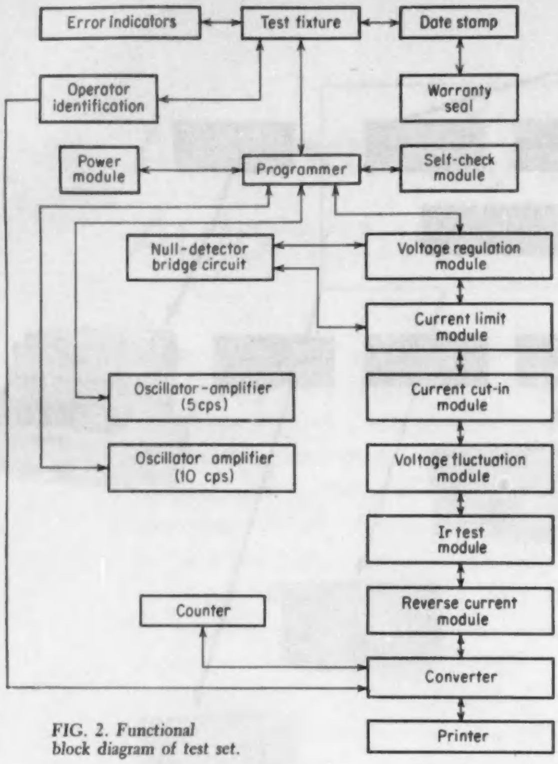


FIG. 2. Functional block diagram of test set.

determination deck on the programmer to energize test result relays and initiate the next test in sequence. The programmer, through appropriate decks, allows these test-result relays to be interrogated later in the test cycle; this gives them a control function. Panel-indicator lights are energized, marking and sealing equipment is actuated, and go/no-go indications are made as a result of this control.

Once the test cycle has been initiated, the operator relinquishes control, and operation sequencing continues until data recording is completed. The block diagram of Figure 2 shows all of the operations.

Self-check and calibration

An internal self-check system, constructed as a separate module, periodically tests the measurement circuitry and test parameter conditions in the inspection equipment. The time between self-check cycles can be set anywhere between a few seconds and several hours. A self-check cycle connects stable test voltages to the measurement circuits, and, by means of logic satisfaction, indicates whether or not all elements are functioning properly. Transistorized voltage supplies with zener diode regulating circuits assure the availability of stable reference voltages.

The reject relays for each condition are actuated when the proper reference test voltage is applied to the specific decks on the stepping switches used in the voltage regulation, current limitation, and point of cut-in tests. These relays, interrogated later in the test cycle to signify the equivalent of a failed regulator, furnish a logical check of the fail or reject circuitry. Reference power-supply outputs are checked by comparison, by alternately connecting them to the same circuits. Another set of relays, the test result relays, energize pilot lights on the front panel to show the operator whether the circuitry is operating correctly.

This automatic, periodic self-check cycle is applied to the quantitative measuring circuits only. The go/no-go qualitative circuits are checked by applying alternate check voltages on each self-check cycle, the test voltages selected being above and below the normal test-limit parameters programmed into the set. This initiation of the self-check cycle is operator-controlled. Electrical interlock prevents use during self-check.

Parameter measurement

Parameter measurement includes quantitative electrical measurement of voltage regulation, current limitation, and cut-in coil operation and qualitative go/no-go indication of voltage fluctuation, voltage drop, and reverse current.

The basic circuits for quantitative measurements consist of steppers, reference voltage-divider networks used in self-balancing bridge circuits, and null detectors. The bridge compares the unknown (regulator) voltage with a precision reference voltage. When a test is initiated through the programmer, an unbalance in the null detector circuit causes the parameter stepping switch to scan the reference voltage divider. Upon nulling, the programmer is signaled and the next parameter measurement sequence started.

After a final balance has been reached and the stepper no longer scans, the stopped position of the stepping switch performs a memory function, controlling: 1) eventual readout of the voltage value to the printer when the test results are within preset limits or 2) actuation of the proper marking pen to indicate the type of failure when test results are outside limits.

Voltage regulation test voltages range from 7.0 to 8.8 volts for 6-volt regulators, and 13.8 to 15.6 for

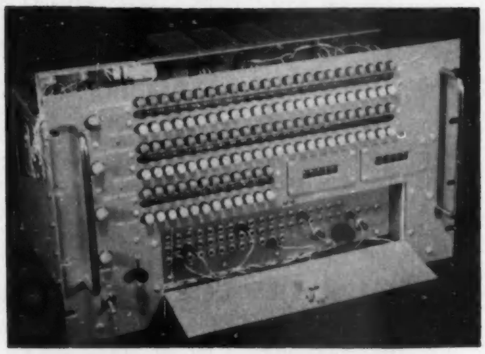
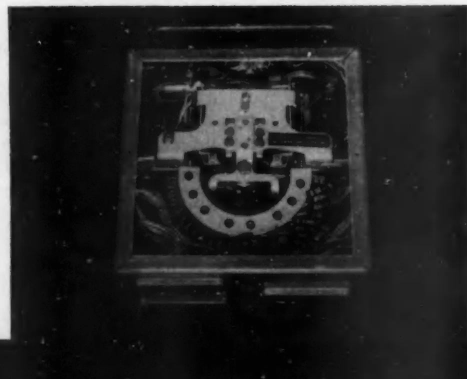


FIG. 3. Test-measurement module showing patch panel.

FIG. 4. Modular construction simplifies maintenance and increases flexibility.



12-volt regulators. The stepping switch changes voltage in 0.1-volt steps so that measurement accuracy is about plus or minus 1 percent. The limits for the current limiting test are 32 to 44 amps and 28 to 32 amps for nominal 6- and 12-volt regulators, respectively.

The operation of the cut-in coil is tested in this way. A stepper, driven by a transistorized oscillator-amplifier at a rate of 10 steps per sec, controls an electronic regulator circuit by means of voltage sampling resistors. This provides a staircase-type voltage, which rises at the rate of 0.1 volt per sec. As the cut-in relay contacts close, the stepper is stopped by a feedback signal. The stepper position also provides a memory function in the control of print-out or fault-marking.

Bi-directional stepping switches are used in these circuits to reduce scanning time and to promote reliability and long life. The divider network/comparison circuits thus can be scanned in either direction in seeking bridge balance, and reset can be accomplished without scanning through all the decks.

Determining the go/no-go parameters does not involve direct measurement techniques. For example, regulator voltage fluctuation, often sporadic, can be checked by a photoelectric meter relay. Test limits are set by marking a go/no-go range on the meter face. On an out-of-tolerance condition, the meter relay actuates a thyratron-controlled relay to control a test result circuit. The same technique checks the *IR* drop.

Reverse current conditions are investigated by passing dc through the regulator and checking for continuity through a circuit that normally should be open. The voltage regulator is properly marked and rejected if any parameter is out of tolerance.

Setting test limits

Switches, plugs and connectors, patch panels, and plug-in wires give versatility to the automatic voltage regulator inspection system. At present, some 24 specifications are referenced for voltage regulator testing, with evidence that many more will be added with advancements in automotive design. This requires provision for rapid change of test conditions.

Upper and lower test limits on the various parameters are set by patch cords in the three rows of plugs located behind a door on the front panel of the test measurement modules, Figure 3. A voltage-changeover switch to the left of the door selects either 6- or 12-volt tests.

Modular construction

The modular-type construction of the automatic test set not only simplifies maintenance, but makes possible system modification without complete redesign. Automatic inspection systems for completely different purposes (testing relays or transformers, for example) can be designed and constructed at a much lower cost with functional plug-in units than by engineering them —and then subsystem circuitry—from scratch.

Each major circuit is incorporated in a 2x8x8-in. module, Figure 4. This means a different housing for the oscillator-amplifiers; program steppers; and voltage regulation, current limiting, and point of cut-in steppers.

QUALITY ASSURANCE

Quality, assured by the test, is further supported by factual test data and monitoring of personnel.

Print-out for quality control

Two types of data are printed out: the digitized results of the voltage regulation, current limiting, and point of cut-in tests (both for the actual inspection operations and for the self-check cycles) and the identification of the person who adjusted the regulator. The latter is obtained in an interesting way. Each adjuster places an identifying mark on the regulators he inspects, and this mark is photoelectrically read and printed out while the regulator is in the test fixture.

The Quality Control Dept. uses this information in conjunction with the measurement data to determine trends in acceptances and rejections, and to tie these trends in with particular personnel and particular production operations.

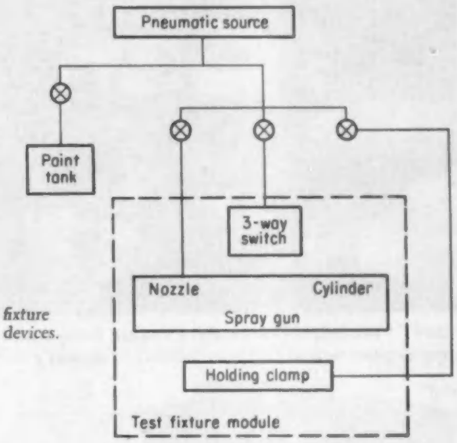


FIG. 5. Test fixture and marking devices.

Date-stamping and warranty-sealing

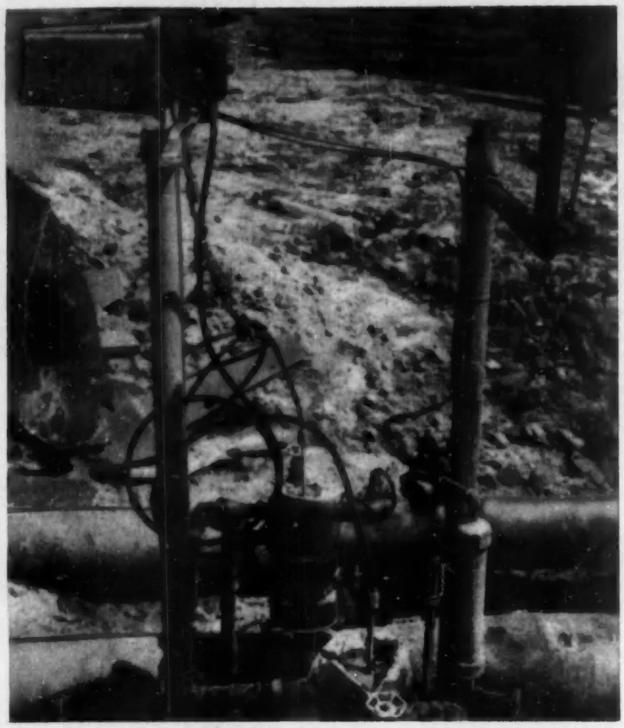
At the conclusion of the six tests, a green lamp will light if the regulator is acceptable. Then the date of inspection is stamped on the cover and the warranty seal is applied. Finally, the pneumatic clamp releases. Figure 5 shows the test fixture arrangement.

Marking of rejected units

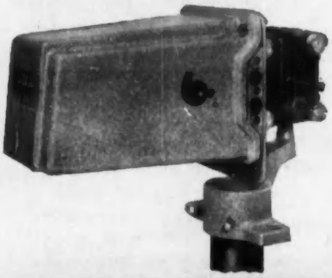
When a unit fails one or more tests, a red lamp lights at the completion of the inspection sequence. The solenoids of one or more pens will be energized and appropriate markings made on the unit. After automatic release of the pneumatic clamp, the operator places the regulator in the rework line.

WHAT DOES THE FUTURE HOLD?

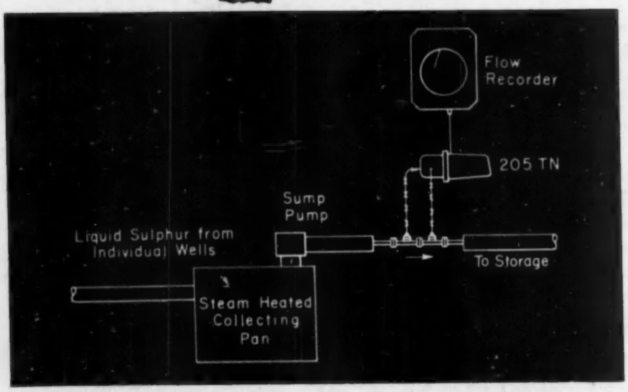
It may be possible to increase the versatility of this test set by, for example, automatically adjusting out-of-tolerance voltage regulators while they are undergoing inspection, and using an automatic plotter to furnish graphic test results. Consideration is also being given to automatic averaging and determination of arithmetic means of the inspection results, in conjunction with the graphic plotter. Tape or card read-in and programming can greatly increase flexibility.



205T Volumetric Differential Pressure Transmitter measuring molten sulphur flow at Freeport Sulphur Company's mines in Louisiana.



No pocketing . . . no purging . . . no plugging . . . with this low-cost transmitter designed for flow, level and differential pressure measurement.



Two all-welded stainless steel sensing diaphragms installed in the pipeline eliminate the need for steam tracing of the lead lines. Result—quicker, less expensive installation; negligible maintenance; process shut-down eliminated.

Freeport Sulphur Company saves time, money on molten sulphur flow control

Taylor Volumetric DP Transmitter costs less to install and maintain

The Taylor 205T Transmitter costs less to install because none of the steam jacketing and insulation needed for a conventional aneroid meter is required. There is no need to insulate leads or meter body, since sulphur comes in contact only with the pressure sensitive diaphragms located either side of the orifice plate in the pipeline.

It costs less to maintain since molten sulphur does not enter any portion of the instrument—no chance of corrosion, no costly clean-out necessary.

Utilizing the force-balance principle, coupled with sealed silicone-filled sensing systems, the 205T Transmitter is the ideal, economical way to eliminate purge and seal problems as well as costly steam tracing. Accurate, sturdy, dependable and low-cost, it can solve your most difficult flow and liquid level measurement problems.

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Using the Load Cell in High-Accuracy Weighing Systems

Strain gage load cells—with their high sensitivity, small size, and essentially stepless resolution—have proven themselves as force-measuring transducers. The author considers their usefulness as elements of high-accuracy weighing systems and warns that their application is a matter for careful evaluation. He points out pitfalls that await the designer and shows how these may be avoided to best use the inherent desirable cell characteristics.

MALCOLM GREEN, Bytrex Corp.

Load cells—resistance strain-gage force-measuring transducers—are useful components in the design of high-accuracy electronic weighing systems. Properties that recommend their use include essentially stepless resolution, high sensitivity, and the absence of hysteresis-producing mechanisms. Compensation is possible for temperature effects on sensitivity, zero reference, and connecting cable resistance. Load cells are elastically stiff, deflecting only 0.001 to 0.015 in. under full load, and are capable of high response speeds. They can be used in both static and dynamic systems.

Practical advantages include their small size and easy adaptation in existing structures. Moreover, they can be hermetically sealed against their environment. Reasonable shock loads will not damage load cell weighing systems because there are no pivots, knife edges, or moving parts.

How they work

Load cells work on the principle that electrical conducting wire, when subjected to mechanical strain, changes resistance proportional to the strain. The conducting wire element (strain gage) is made part of a Wheatstone bridge circuit in which the variation of electrical signal output due to the strain-induced resistance change may be measured. The box on page 123 describes the basics of strain-gage load cells.

Two general types of resistance-wire load cells are available—bonded wire and unbonded wire. In the bonded wire gage, the wire element is sandwiched between two thin pieces of insulating material and the sandwich bonded to a load-carrying member. In the unbonded wire gage, the wire is wound about two elements, one of which may be displaced with respect to the other. In each type, the strain produced by forces applied to the load-carrying member on which the gage is mounted changes the electrical resistance of the wire.

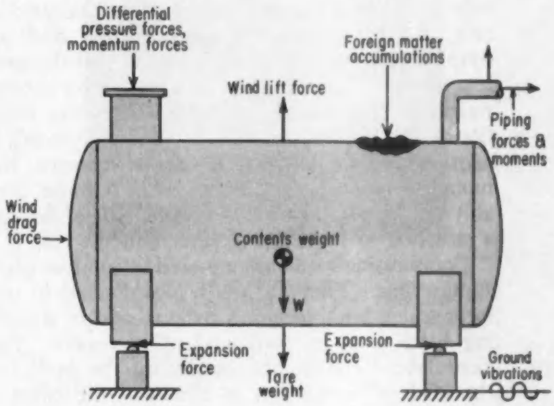


FIG. 1. A tank supported on load cells for contents weight determination. The forces applied to the load cells include many components likely to produce weighing errors.

Manufacturers package load cells in enclosures that provide mechanical protection, means for fastening the cells down and for transmitting force to them, and sometimes protection for the internal load-carrying element from side forces. It is relatively easy to mount the cells and incorporate them

into weighing systems that will produce accuracies approaching ¼ percent of full scale. However, to design systems having accuracies of 1/10 percent or better, the load cells must be treated as more than structural elements. A consideration of the weighing problem shows why.

In general, load cells can accurately measure axial forces applied to them. But they cannot distinguish between forces produced by material being weighed and forces caused by such extraneous effects as piping, dirt accumulations, and ground vibrations, Figure 1. Too, side forces may affect load cell sensitivity. All such extraneous effects, other than the primary axial weight force, must be minimized by the designer interested in accuracy in a load cell electronic weighing system.

Applying force to the cell

Load cells are available for compression loads only, for tension loads only, or for compression and tension loads (those for the last are commonly called universal cells). Selection is determined by the configuration of the body to be weighed and by economic considerations. Universal and tension cells generally are more expensive than compression cells, but they can often be justified if their use simplifies the mounting configuration. If the problem is one of converting an installation to electronic weighing, the choice is limited by existing conditions. For example, it may be desired to weigh an existing 200,000-lb capacity outdoor storage tank mounted on saddles. Tension cells would probably not be practical because of the cost of building a structure to suspend the tank from the cell.

Compression load cells are used in most weighing applications. They are easily incorporated in platform scales, tank weighing systems, and in supporting batch hoppers, bins, and other vessels. Sufficient lateral compliance usually can be built into the load cell mounting to eliminate the effect of excessive side forces.

Tension load cells are particularly useful for two special weighing problems. One is where the physical arrangement of equipment naturally dictates their use, such as in a monorail weighing system. The other is where excessive motion due to thermal effects or to load-produced dimensional changes must be tolerated. It is often easier to introduce flexibility into tension systems by the use of long suspension members or universal-type joints than it is to achieve equivalent flexibility in compression systems, where stability requirements may dominate.

Which weighing system?

Load cell weighing systems may be divided into two weighing classes: those that support the entire weight structure on load cells and those that support only part of the total weight on load cells. The partial weight system is economically desirable because the fewer cells required reduces system cost.

However, a most important condition for use of the partial weight system is that the center of gravity of the weight body remain fixed. This condition is not easily met in weighing solids in bins and hoppers. In a weigh-hopper that is being filled, center of gravity will probably change with level of material and as local vibration, humidity, and physical variations in the material change the angle of repose. If the center of gravity shifts, distribution of vertical forces will change, producing an inaccurate weight indication.

Shifting c. g. may also be encountered in liquid weighing systems. Cylindrical dairy milk tanks, for example, are often installed on a tilt to insure complete drainage. As liquid is withdrawn, the c. g. shifts toward the low end and produces an error.

Horizontal forces, usually neglected in weighing systems, can also produce errors in partial weighing systems. Assume that a partial weight system hopper is being fed by a long, flexible run of horizontal pipe. Though vertical forces exerted on the hopper by this pipe can be made so small as to be negligible, a horizontal force on the pipe (such as that produced by thermal strain) will produce moments on the hopper which in turn produce a change in vertical force distribution on the load cell and the non-weighing support.

The most important thing for the designer to remember is that where it is impossible to control load distribution of material being weighed or to predict and control other forces on the weighed body, the entire body must be supported on weight sensitive members for maximum accuracy.

How many and how big?

Once the class of weight system has been decided upon, the number of cells to be used must be determined. For compression cells where eccentric loading will be small, one- or two-cell systems with flexural guides often attain required stability. Three is the minimum number of cells which can be used without depending on flexural guides for stability. But many weighing systems, such as platform scales, do not easily adapt to three-cell support, so that four-cell weighing systems are most common; however, up to eight cells have been used. Stability can be obtained in tension systems with just one cell.

Like most measuring instruments, load cells are best used as close as possible to their rated capacities. Maximum signal output may then be obtained and the relative importance of instrument error reduced. Sometimes, however, it is necessary to use the cells below their rated capacity to provide protection against possible force overloads. A system consisting of a small fuel tank hanging from a 50-lb capacity load cell can be easily damaged by a 200-lb pipefitter standing on it to reach his work.

Again, a railroad track scale designed to weigh one car at a time may be subjected to the weight of the locomotive that "spots" the car. Then, too,

The basics of strain-gage load cell design

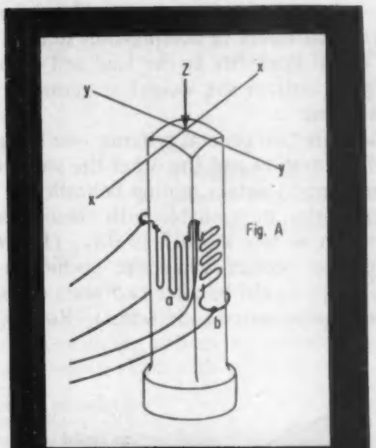
Figure A depicts the sensitive element of a bonded wire compression load cell. Four gages are cemented to the column, two (a and c) with grids parallel to, and two (b and d) with grids perpendicular to the force axis. As compressive force is applied, gages a and c tend to decrease in length; diameter of the wire then increases, and gage wire resistance decreases. Gages b and d are put in tension (Poisson effect), and their resistance increases. With input voltage of the indicated polarity, output voltage changes from no-load balance in the direction shown in Figure B. The output voltage is augmented by having gages b and d strain perpendicularly to gages a and c; straining them in the same direction would decrease output.

Temperature change affects both the output voltage at zero load and sensitivity. Gage wire is selected for minimum temperature sensitivity. However, if the gage resistance changes due to temperature are not identical, bridge balance will change even at constant load. The measuring instrument cannot discriminate between temperature- and load-produced balance changes.

Knowing rate of balance change with temperature at zero load and the gage resistance, the manufacturer can determine the amount of temperature-sensitive wire to be placed in series with one arm of the bridge (as at a'). This wire is placed in contact with the column for good heat transfer, but is electrically insulated from it. This compensation is effective only when all gages are at the same temperature. In designing highly accurate systems, however, transient thermal conditions must also be considered.

A temperature-sensitive resistance, **M**, is placed in series with one or both input leads to compensate for modulus of elasticity change in the column due to temperature. This resistance increases with temperature, dropping the voltage applied to the bridge. Thus, although the gage strain increases with temperature, the voltage output for constant load and input voltage is unchanged. It is possible to reduce temperature effect on sensitivity to less than 0.001 percent per deg F.

A stable calibration resistance, **C**, may be placed in series with one or both of the input leads. Determined by loading tests, the calibration resistance is selected to adjust the percentage of input voltage impressed across the gages. The calibration of precision-class load cells is normally set to within plus or minus 0.1 percent of full scale. Normally a shunt resistor, **S**, is also added to the bridge circuit to specifically set the input resistance. This facilitates transducer interchangeability, especially when used with a load-sensitive instrument.



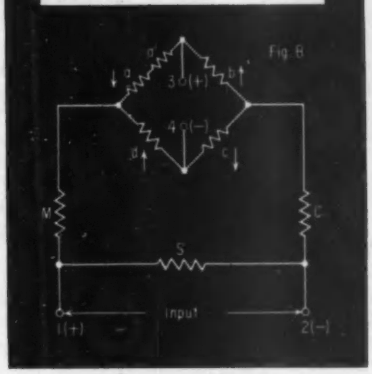


FIG. A. Sensitive column element with four bonded wire compression gages. Gages c and d are mounted on column faces opposite, respectively, gages a and b.

FIG. B. Load cell gages as part of Wheatstone bridge measuring circuit.

shock overloads are produced by rolling stock moving onto the track scale and the braking reaction when a moving car is stopped on the scale. Other systems may be subject to different overloads; each system must be examined carefully by the designer.

A silo, supported on load cells at its base, may be overloaded by wind forces. The overturning moment in the vertical plane will have the effect of increasing the load on some cells and decreasing it on others. Too, in an interdeterminate load distribution system (for example: a rigid body supported on four cells), there is the possibility that one cell will be lightly loaded or not loaded at all, causing the other three to assume the burden.

If the load cells have nonlinear responses, redistribution of force among the cells in a system will introduce error. Response characteristics of the cells may be the determining factor in selecting the proper ones. Some load cells have parabolic response; when used over a small portion of their rated capacity, they can be considered essentially linear devices. Compensating networks in the instrumentation might be required to offset the nonlinearity of a wider range.

Mounting arrangements

Load cells measure accurately only the axial forces applied to them. Since good data are not available on the sensitivity of load cells to side forces, design should prevent imposition of transverse forces or of

forces which, inclined at an angle to the cell axis, can be resolved into normal and transverse force components. A common procedure for avoiding longitudinal forces in compression systems is to provide lateral flexibility in the load cell mounting and to rigidly restrain the weight structure in the horizontal plane.

There are two general systems, one using a sliding or rolling motion and the other the strain in an elastic member, to obtain motion beneath the load cells. Sliding plates are available with claimed coefficients of friction as low as 0.05 to 0.1. (However, it is difficult to predict what the coefficient between these plates would be after two years of exposure to severe environmental conditions.) Rollers, too, offer

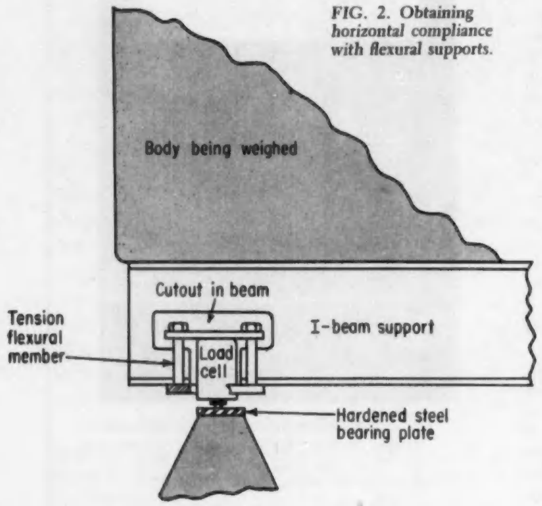


FIG. 2. Obtaining horizontal compliance with flexural supports.

restraint as the surfaces corrode, deform plastically, or accumulate foreign particles.

Mounting configurations employing elastic deflections (flexural supports) have found increasing acceptance. They can be accurately calculated and depended upon to maintain their characteristics over long periods of time. Though the restraining forces produced by flexural supports cannot be made zero, they can be made small enough for most applications.

Various schemes are available for obtaining horizontal compliance through the use of flexural supports. Figure 2 illustrates a variation in which the load cell supporting members are put in tension to avert buckling from large motions at high loading. Though relatively expensive to execute, especially for high weight capacity systems, this method is capable of sustaining large deflections. It is incorporated in a weighing system used in setting LOX and fuel level calibration marks on Jupiter missiles. To compensate for load cell nonlinearity, the weighing range was divided into 10 increments, each tailored to follow the stability and ensure a predictable load distribution. The guaranteed accuracy of this system was 1 part in 3,750. Timer and associated controls determined flow rates.

A well-designed weighing system is a compromise between opposing factors. Though the weight-supporting structure must be soft or flexible to equally distribute weight among all the cells and to prevent imposing excessive longitudinal forces on any one of them, the structure also has rigidity requirements. If cells realign as they are loaded, inaccuracies, introduced by changes in zero reference or in system calibration, can accrue. These are most serious when the angle of the load cell axis with the vertical changes by a large amount, since the force component applied to the cell varies as the cosine.

In using compression cells, bearing conditions between the spherical loading button and the force-applying plates are also important. If the plate has local depressions, a nonuniform pressure between it and the load button may produce a condition equivalent to off-center load. If the plate surface is soft, permanent indentation can result, causing adverse loading conditions upon a change in relative position between the load cell and the plate.

Watch out for sources of error

The designer must foresee upset factors that may appear long after the design leaves his board. Many carefully designed and executed weighing systems have failed to produce their designed-in accuracy because of improper operation and unfavorable environmental conditions. An airplane being weighed outdoors may generate some lift that will result in error. Tanks with heating or cooling coils are subject to weighing error unless the coils are consistently full (of constant density material) or empty when weights are recorded. Rain and snow accumulations on a tank are usually removed before weighing, but often weight change of a tank's hygroscopic insulating jacket, due to humidity, is overlooked.

Finally, weighing system accuracy can be undermined by wholly unpredictable circumstance. After several years of successful operation in a processing plant, a tank weighing system became inaccurate. Investigation revealed that a steel ladder, welded to the tank from a catwalk below, introduced a restraining force which caused the error.

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More Reliable Hydraulics in Flight Control

Once reliability criteria have been selected for a particular hydraulic flight control system, there are steps that can be taken to improve the reliability of the system. Redundant chains, isolation valves, and various switching arrangements can supplement the normal procedure of choosing reliable components and using them conservatively. Good reliability data is scarce.

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Practical and reasonable criteria for reliability of hydraulic flight control systems are difficult to set forth in a specific form. Reliability of flight control systems can be loosely defined as the probability that no failures will occur which would prevent successful controlled flight. This implies various degrees of allowable failures depending upon the phase of the mission.

A minimum requirement might be sustained flyability and landability for preservation of the aircraft and crew, but control requirements then vary with the configuration of the aircraft, the type of control system used, and the mission of the aircraft. In all cases, at least partial control in both elevator and aileron functions, sufficient to recover from limited maneuvers, is a minimum requirement. And the need for rudder control to counter yawing tendencies during landing is becoming recognized as important to safe operation of advanced military aircraft. Hence, for sustained flyability and landability, flight control system reliability is the probability that no failures will occur which would prevent exercising at least partial control in all three primary flight control axes.

Other criteria for system failure can be selected depending upon the particular problem. For example, it might be desirable to assume that all control axes must function perfectly during those phases of a mission prior to and including combat, while the return flight criterion could be relaxed to minimum flyability and landability.

To be entirely realistic, any measure of effectiveness (Ref. 3) adopted for evaluating the hydraulic flight control system should go well beyond reliability alone. In the end, the final governing factor is the effectiveness of the aircraft as part of a larger weapon system. Such a larger view reflects compromises in the design of systems within the aircraft to achieve a maximum of overall dependability. The hydraulic flight control system must then be considered in terms of all other systems in the aircraft, and other important design objectives such as availability (maintainability), invulnerability, and overall performance assume roles of importance along with reliability.

Component reliability

In general, component failures exist in three characteristic categories: initial or wear-in failures, intermediate chance failures and wear-out failures, Figure 1. The first of these is primarily the result of manufacturing problems, defective materials and assembly, damage in shipping from the factory, etc., and induces a high early rate of failure which decreases rapidly with operational time. These high initial rates can be controlled through such measures as careful inspection, improved quality control procedures, and wear-in or aging runs at the factory.

Chance failures are those which occur during normal operational periods. Failure rates during this period are essentially constant, since failures are characterized by randomness, with failure probability being independent of the operational age of components. Also, chance failures are essentially uncontrollable and reflect the occurrence of random environmental stresses which exceed the capabilities inherent in the basic design of the unit. Failure rates during this period can be reduced only by extensive redesign to increase environmental tolerance capabilities or by reduction of the probability of occurrence of environmental stresses exceeding a given tolerable value. The former can be obtained by increased ruggedization through such things as improved materials of construction, while the latter can be accomplished through conditioning of the local environment surrounding the component.

Wear-out failures are essentially old age failures, with ordinary wear being the predominant cause of failures. These failures are generally distributed normally around a mean wear-out lifetime.

Reasonably well-developed components will generally exhibit little tendency toward wear-in failures, and will have a relatively long operational life during which chance failures predominate. Component wear-out failures as such also appear to have little significance within the operational life observed for the majority of operating systems in military applications. This is particularly true of aircraft compo-

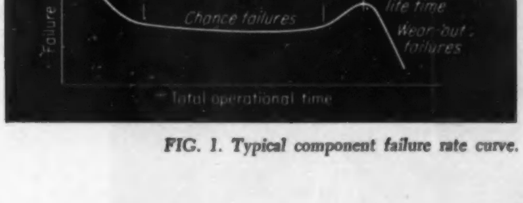


FIG. 1. Typical component failure rate curve.

nents since frequent corrective maintenance schedules tend to encourage replacement of components showing wear before failure occurs. Hence, chance failure relationships will generally apply to predicting the reliability of components in most analyses of the reliability of aircraft systems during normal operational periods.

System failure analysis

Breakdown of a hydraulic flight control system into sub-groups of components for analysis (as detailed in Ref. 1) will vary in form and extent depending upon the criterion selected for system reliability evaluation. In general it is convenient to separate power sources (including reservoirs, pumps, accumulators, main filters, and coolers) from actuation subsystems in the basic block diagrams. A typical hydraulic flight control system broken down in such a fashion is shown in Figure 2.

This particular system is widely representative of the type used on modern fighter aircraft and consists of two separate power sources, each of which supplies hydraulic pressure to separate halves of dual actuators in each flight control axis. Hydraulically, the system then consist of two parallel sets of series subsystems, each capable of providing the required control function around all flight control axes. The common mechanical connection linking the dual actuators and the control surfaces are indicated by the dashed lines between the control subsystems blocks in each of the individual control axes.

With this breakdown, reliability of the overall system can be established by combining the reliability levels of each of the individual subsystem blocks, considering all possible combinations of failure events which can cause system failure in accordance with the selected reliability criterion. For example, using the criterion of sustained flyability and landability, system reliability becomes the probability that no failures will occur which would incapacitate dual branches of any single flight control axis. During any flight operational period each component or subsystem can be considered for all practical purposes as a Bernoulli trial. In other words, there can be only two outcomes of a flight period—either the component or subsystem fails or it does not fail.

Combinations of possible component or subsystem failure events to describe a failure event for the system can be treated by using the rules for unions and intersects of events as developed in probability theory (Ref. 2, Ch. 1). In accordance with accepted definitions, the union of events is the realization of at least one of a group of events, while the intersect refers to the realization of all of the possible events. In the simple two element series array shown in Figure 3 the system will fail if either A fails or B fails or both A and B fail. This is simply the union of events, failure of A and failure of B.

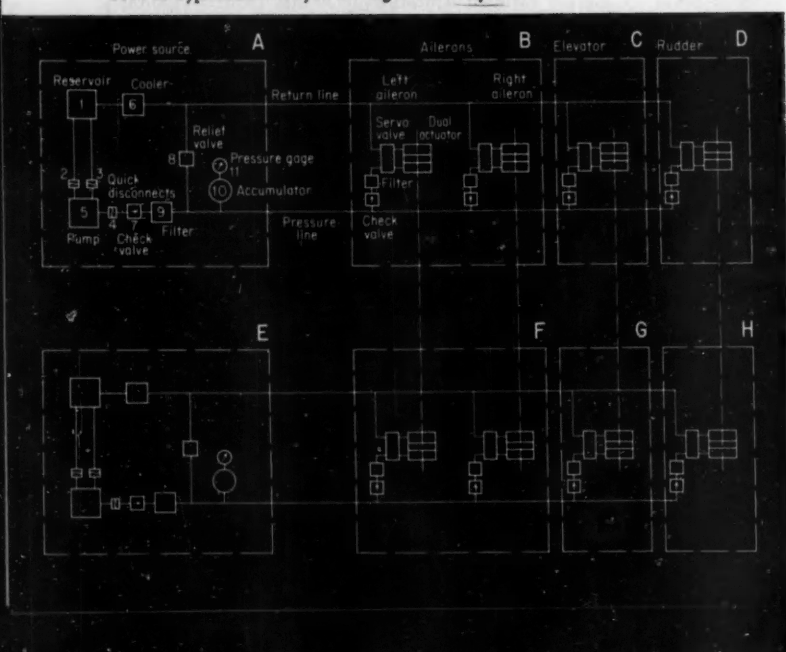
Considering the system of Figure 2, both leak and nonleak type failures are possible in each of the subsystem blocks *A, B, C, D, E, F, G,* and *H*. These two types of failures can be combined in each of A and E if it is considered that either type of failure in the power source will be equivalent to loss of fluid pressure in the corresponding system branch. The combinations of subsystem failure events to produce possible failure events of the system are as follows:

- At least one control axis will fail if one branch of the system loses pressure, and failure occurs in any portion of the opposite branch.
- The system will also fail if any one of the flight control actuator subsystems in one branch fails to function, and pressure loss occurs anywhere in the opposite branch of the system.
- The third way in which the system can fail is for functional failure to occur in both dual branches of at least one flight control axis.

The overall system reliability, or the probability that none of these three combinations will occur is the intersect, or product, of the probabilities of nonoccurence of each combination. This is equivalent to one minus the union of the three failure events. All possible combinations must be included in establishing the failure event for the system as a whole.

This method of combining subsystem failures to establish system failure probability can be used to evaluate basic variations in system form. For example, utility systems such as landing gear, flaps, divebrakes, etc., may be appended to one branch of a dual flight control system. In this case one power source supplies pressure for both the utilities and one branch of the flight controls; hence, a severe leak in a utility system can result in loss of one branch of all three dual flight control axes.

FIG. 2. Typical aircraft hydraulic flight control system.



Estimated Hydraulic Component Reliability Levels (one-hour)

Reservoirs	0.99995
Pumps	0.99922
Accumulators	0.99976
Filters	0.99993
Check valves	0.99999
Relief valves	0.99997
Coolers	0.99993
Pressure gages	0.99987
Actuating cylinders	0.99964
Servovalves	0.99980
Lines and fittings	0.99999+

Resulting system reliability is lowered when the probability of leak failures in the utilities is included in the analysis. In systems of this type, manual or pressure-operated isolation valves may be used to improve system reliability by preventing failures in utilities from affecting the flight control system. The system of Figure 4 contains such a valve which isolates the utilities in the event of loss of pressure downstream in the utility system. In this case leak failures in the utilities can cause failure in the lower branch of the systems only if the isolation valve fails to function when called upon, or the valve itself ruptures.

Manual isolation valves are operated by the pilot to shut off pressure to utilities which are not used except during takeoff and landing, thus preventing possible failures in these utilities from affecting the flight controls during the major portion of the flight. Pressure-operated locks activated by pressure loss in the opposite branch of the flight control system are effective in preventing the isolation valve from being opened and protect against complete loss of flight control in the event that leak failures have developed in the utilities.

Various switching arrangements are also used to improve system reliability, particularly in cases where one of the branches of a dual system may be an auxiliary or standby system, or where single actuators are used with dual power sources. In the simplified system of Figure 5 the transfer valve will sense pressure-loss failure in the main system and automatically switch to the auxiliary system. This system will fail, then, 1) if *B* fails from loss-of-function (nonleak), 2) if A or *B* or both A and *B* suffer pressure-loss failure and V fails to transfer, or 3) if both of these sets of events occur. Switching arrangements are also subject to the occurrence of switching when not called upon to switch, thus introducing an additional failure event.

The previous examples are all based on the minimum flyability and landability criterion discussed earlier. Selection of abort criterion allowing no failures at all in the system would result in a reliability level which is the product of the reliabilities of all the subsystem blocks. The resulting reliability level in this case will, of course, be considerably lower than that for minimum flyability and landability.

Availability of reliability data

Background data for establishing the mean time between failures for hydraulic flight control system components is in very short supply. Routine reporting systems now in use in the military services supply information useful in correcting deficiencies in components. However, they provide no information regarding total component hours of operation for components which do not fail, and thus no means of establishing reliability levels under normal conditions. Other data from commercial operations and testing programs is quite limited and scattered.

Some of the most useful data resulted from an operational survey carried out by the Bureau of Aeronautics in 1954. In this survey total operational time on all aircraft in the sample group was recorded to establish total component hours of operation during the trial period. At the same time all failures occurring in the sample group were recorded in detail on a special reporting form. These data, which represented reports of over 5,500 failures occurring in 2,558 operational jet fighter and attack aircraft were recorded on punched cards and processed to estimate component mean time between failures for all of the major classes of hydraulic system components.

FIG. 3. Simple series arrangement of two subsystems.

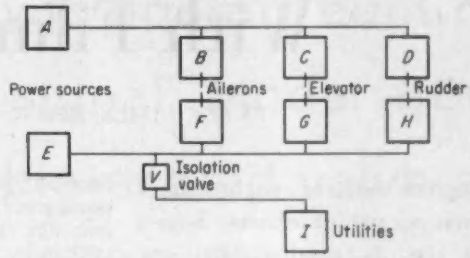


FIG. 4. Flight control system with utilities on one branch.

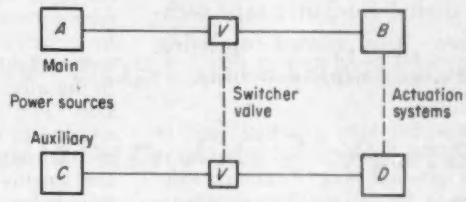


FIG. 5. Simplified system with switcher valve.

Resulting mean time between failures for hydraulic components operating under the environmental stresses imposed by the types of operations represented by the survey group varied from 200,000 hours for lines and fittings to approximately 1,250 hours for engine-driven pumps. Representative reliability levels based on a one-hour operating time as computed from these data are illustrated in the table. These reliability levels include both leak and nonleak failures. On the average for all components, *leak-type failures predominated*, constituting nearly eighty percent of all reported failures.

Reliability levels shown in the table are necessarily the result of analyzing a rather limited sample, and caution should be exercised in applying them to systems which may operate under conditions widely different from those represented by the data. Since they are based on aircraft operational data they are not applicable to industrial systems, for example.

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Searching and Updating Easy With Film-Tape Records

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Complete sets of engineering drawings, patent claims, business records, catalog data, or legal documents can be found and reproduced quickly by this system that marries microfilm and digital computer tape techniques. And record updating can be done while searching.

There has been a serious need in engineering, business, and government for a practical way of automatically searching for and updating or retrieving drawings, papers, documents, and records from master files and libraries. Electronic digital computers have been automatically searching for, reading, and revising data stored on magnetic tapes for some time. But storage of complete documents, especially drawings and photographs, on magnetic tape is presently unfeasible, and practical indexes and abstracts are usually insufficient. Present microfilm storage techniques reproduce complete records, but are slow in searching and particularly difficult to update.

The accompanying figure is a block diagram of an experimental system design that adds the speed and easy alterability of computer tapes to the permanence and completeness of a microfilm file. In this system a multitrack magnetic stripe is laid alongside the photographic emulsion on a wide microfilm base. The photographic and magnetic information is divided into groups or blocks of equal size. An input tape moves in a forward direction toward reel 2, although it can be reversed. The input read-write unit reads coded information relating to the adjacent photographic information. The photographic information on the tape may optionally be scanned by the photoelectric unit to derive the lengths and number of photographic frames for later reference, and similar data may be recorded on the digital track. The lamp unit contains a gaseous discharge lamp used as the light source for recording selected information onto the output tape.

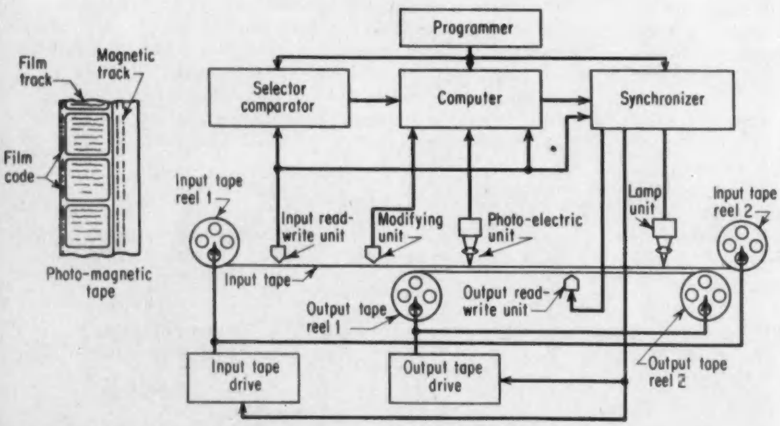
The programmer unit accepts inquiries from the operator via a keyboard or similar device and transmits it in the form of a "question code" to a computer shift register which develops code pulses for each bit of information of the question for comparison with the pulses from the input read-write unit in the selector comparator. Code bits may be compared synchronously or asynchronously.

The synchronizer controls the transfer of photographic data from the input tape to the output tape as well as the transmittal of the tape question-answer code to the magnetic portion of the output tape. A stopping-distance counter is preset from the programmer and initiated by an acceptance pulse from the selector comparator. As the input tape travels toward the lamp unit, the photoelectric unit detects the passing of the edge of each frame and sends an edge-of-frame pulse for each passing frame to the stopping-distance counter. When the number of pulses from the photoelectric unit equals the number preset by the programmer, the stopping-distance counter is cleared, and the next edge-of-frame pulse will stop the input tape.

A number-of-frames counter preset by information on the input tape determines the number of sheets or frames to a particular document set, all of which are to be reproduced in sequence on the output tape. If several copies are desired, a number-of-copies counter steps the output tape a calculated distance between copies of Frame 1 of a set, steps the output tape backwards while exposing Frame 2 adjacent to the copies of Frame 1, forward again for Frame 3, etc.

Updating techniques

The straightforward method of updating the photographic record is to merge the current frames with the principal records by reproducing both on another film-tape. The newly created tape will contain the updated record. But a novel updating technique can be used with this system: updating in-line with a specific search. In this technique new documents can be put on a "current file" tape in random order if there is no unexposed film capacity, and the document identification number as well as the number of frames involved made part of the original digital record. Thus, when searching, the device is instructed that a portion of the photographic record is stored at a remote location in a "current" file.



Experimental microfilm-tape information retrieval system.

Thermistors Measure Low Liquid Velocities

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A special instrument had to be designed to explore the three-dimensional flow pattern of filtered, deionized water in a large, partially baffled tank. Water temperature was nearly uniform and between 20 and 45 deg C. The available openings in the top of the vessel were 1.3 inches in diameter, thus limiting the maximum horizontal dimensions of any velocity-sensing element to about 1 in. Local water velocities to be measured varied from 0.1 to 5 ft per sec.

A thermistor in a hot-wire bridge circuit was found to be a practical solution after noting certain disadvantages of other instruments.

- Pitot tubes would see too small an impact head at the low velocities to be measured, and special detection methods would have to be developed.
- Propeller-type flowmeters that were commercially available were too big.
- Magnetic induction meters, also too big, would not work in deionized water.
- Heated thermocouples would have to operate at such a high temperature that local boiling and erratic changes in heat transfer would result.
- Tracer injection methods would contaminate the deionized water.

The hot-wire anemometer operates on the change in resistance of an electrically heated wire with temperature and thus with fluid velocity, and has been widely used to measure local gas velocities. Its use in liquids has been restricted due to accumulation of scale, formation of vapor bubbles, stress relief, collection of debris, and aging, all of which affect the calibration of the wire. The scaling and collection of debris would not be serous problems in filtered and deionized water, however, and the other instability factors could be overcome by operating the wire at relatively low temperatures. The lack of velocity sensitivity inherent with low temperature operation was offset by replacing the platinum wire ordinarily used with a thermistor, which has a much greater temperature coefficient of resistance. Between 0 and 150 deg C, the specific resistance of a thermistor decreases by a factor of 100 whereas that of platinum increases only three times. Thermistors are very stable, showing a resistance change of only one percent after five years at 105 deg C.

Temperature compensation

A modified form of the Wheatstone bridge circuit usually employed with hot-wire anemometers was chosen for the thermistor instrument. In normal anemometry the effect of fluid temperature on the sensing element can be neglected, since the wire is much hotter than the moving fluid. The thermistor, however, was to operate much closer to the temperature of the fluid. To compensate for fluid temperature, a second thermistor of relatively large resistance but of the same temperature coefficient was placed in the adjacent leg of the bridge as shown

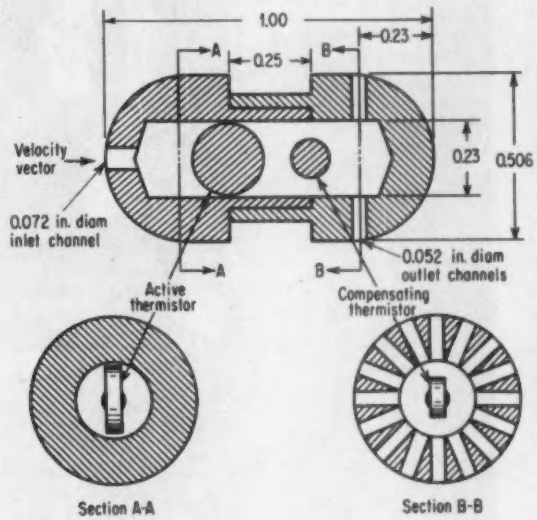


FIG. 2. Aluminum enclosure for making velocity pickup sensitive to direction of liquid flow.

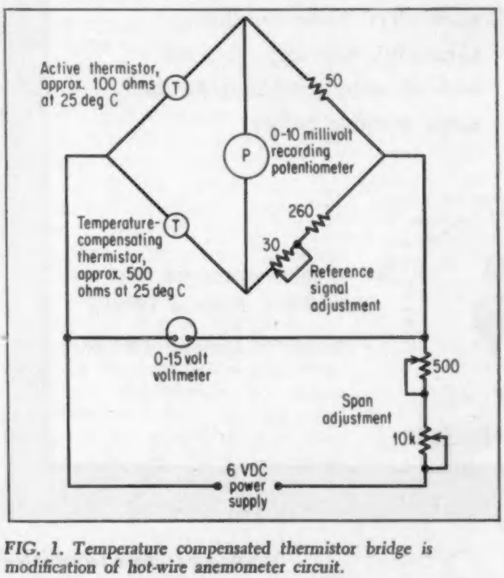
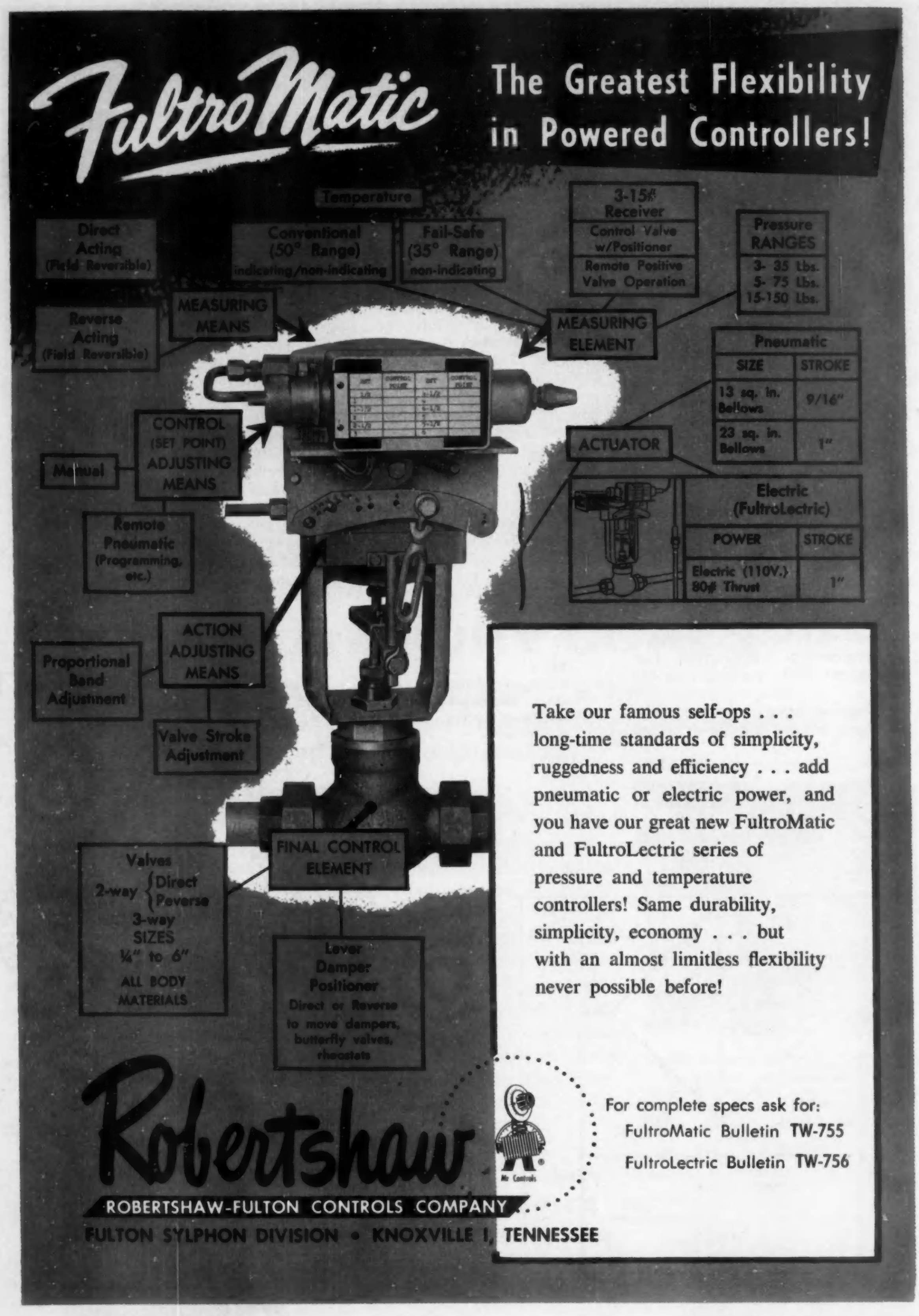


FIG. 1. Temperature compensated thermistor bridge is modification of hot-wire anemometer circuit.

FIG. 3. Directional velocity pickup mounted in yoke for sensitivity tests.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15-150 Lbs.
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MEASURING MEANS
MEASURING ELEMENT
Pneumatic
SIZE | STROKE
13 sq. in. Bellows | 9/16"
23 sq. in. Bellows | 1"
ACTUATOR
CONTROL (SET POINT) ADJUSTING MEANS
Manual
Electric (FultroLectric)
POWER | STROKE
Electric (110V.) 80# Thrust | 1"
Remote Pneumatic (Programming, etc.)
ACTION ADJUSTING MEANS
Proportional Band Adjustment
Valve Stroke Adjustment
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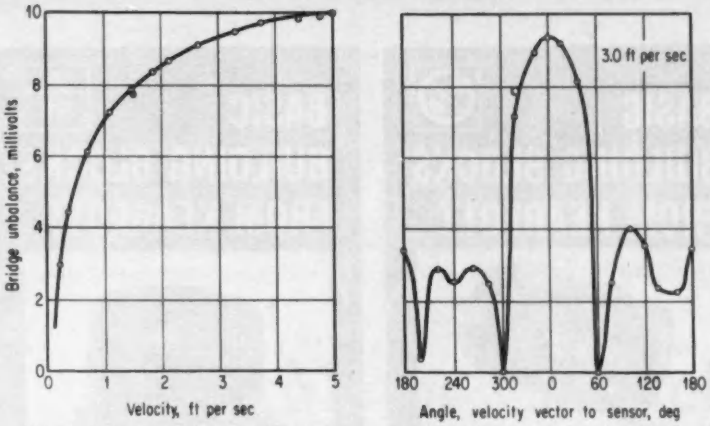


FIG. 4. Velocity and directional sensitivity curves for thermistors in enclosure of Fig. 2 and 3.

in Figure 1. Both thermistors were immersed in the moving fluid and operated at the same voltage (the bridge is only slightly unblanced during operation). Therefore, because of its greater resistance, the temperature compensating thermistor operates at a lower temperature than the low resistance thermistor and is relatively insensitive to velocity. The bridge is then much more responsive to changes in the velocity of the fluid than it is to changes of fluid temperature.

Enclosure development

The thermistors are insensitive to direction of flow, so it was necessary to design a direction-sensitive enclosure for them. The aluminum enclosure detailed in Figure 2 was arrived at after much experimenting. Various shapes of tapered end contours were tried, and the hemispherical ends were found best. The size and the length-to-diameter ratio of the inlet orifice were optimized experimentally for good response to changing mean velocity consistent with good directional sensitivity. Different arrangements were tried for the discharge orifices, too—from axial to the radial configuration in Figure 2—and their size was found critical to balance between turbulence around the thermistors and clogging by air bubbles or dirt.

The thermistor enclosures were mounted at the end of a yoke as in Figure 3 so they could be rotated horizontally or vertically. They were then tested in a shallow open tank by driving the yoke across the tank with a variable speed motor at velocities up to 5 ft per sec. The angle of attack was varied in these tests to derive directional sensitivity curves like the one in Figure 4.

Three Solenoids Make Low-Wear Stepping Motor

A new stepping motor has been developed by Telefunken GmbH (Backnang/Wurtt, Germany) based on a unique arrangement of electromagnets. The motor needs no sliprings or gears, and its moving parts get very little wear. Six watts input produces a torque of 14 in.-oz during each step, which is sufficient to operate a good-sized wire-wound rheostat.

The operating principle is illustrated schematically by Figure 1. The electromagnets actually used are pot-shaped for higher efficiency. The first armature (disc-shaped) is held in a neutral position between two actuating magnets by flat springs when the motor is not energized. This first armature disc moves toward whichever magnet is energized, depending on the direction of rotation desired, and returns to its neutral position when the magnet is de-energized.

Motion of the first armature disc is coupled to the third pot-shaped magnet by a slot-and-follower-pin linkage. When energized, this coupling magnet attracts the second armature disc which is connected by a diaphragm spring to the output shaft. The energized coupling magnet and the sec-

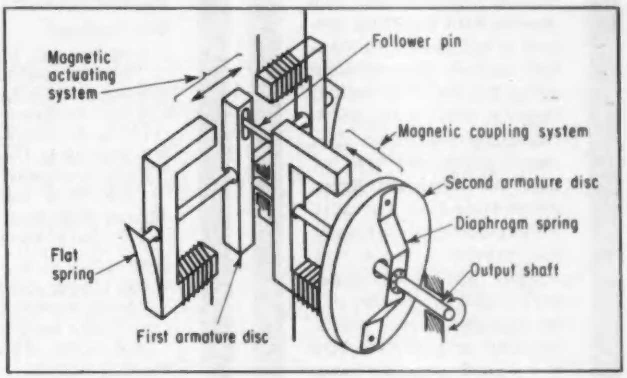


FIG. 1. Schematic representation of stepping motor. Pot-shaped magnets are shown as C-shaped pieces and first armature disc as bar for simplicity.

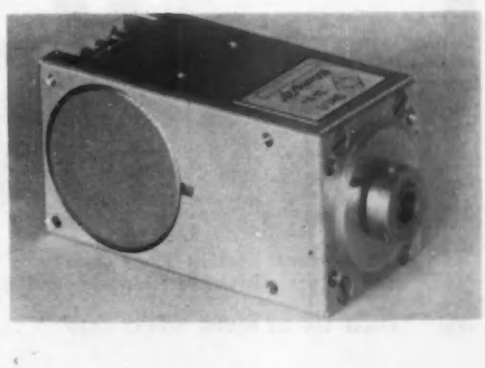
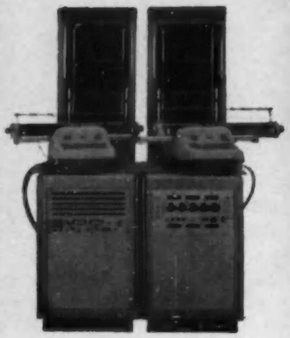


FIG. 2. A 24-volt, 6-watt, 14-in.-oz. stepping motor capable of 5 rpm at 10 steps per sec.

BASIC BUILDING BLOCKS FROM KEARFOTT



Data Logging

Kearfott's broad line of test equipment includes the Scanalog 200-Scan Alarm Logging System which monitors, logs and performs an alarm function of up to 200 separate temperature, pressure, liquid level or flow transmitters. This precise data handling system is equipped with manual controls for scanning rates, automatic or manual logging, data input relating to operator, time, day, run number and type of run. 200 numbered lights correspond to specific points being maintained and provide a visual "off normal" display for operator's warning. System can be expanded to 1024 points capacity and 2000 points per second scanning rate.

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

Floated Rate Integrating Gyros

Specifically designed for missile applications, these Kearfott miniature gyros operate efficiently at unlimited altitudes. Their outstanding accuracy and performance make them superior to any comparably-sized units on the market. Hermetically sealed within a thermal jacket, these gyros are ruggedly designed and completely adaptable to production methods. Performance characteristics that are even more precise can be provided within the same dimensions.

TYPICAL CHARACTERISTICS

Mass Unbalance:
Along Input Axis: 1.0°/ hr maximum untrimmed
Standard Deviation (short term):
Azimuth Position: 0.05°/hr
Vertical Position: 0.03°/hr
Drift Rate Due to Anisoelasticity
Steady Acceleration: $.015°/hr./g^2$ maximum
Vibratory Acceleration: $.008°/hr./g^2$ maximum
Damping:
Ratio of input angle to output angle is 0.2
Characteristic Time: .0035 seconds or less
Weight: 0.7 lbs.
Warm-Up Time: 10 minutes from −60°F
Life: 1000 hours minimum

BASIC BUILDING BLOCKS FROM KEARFOTT

Electrohydraulic Servo Valve

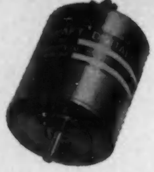
Kearfott's unique approach to electrohydraulic feedback amplification design has resulted in a high-performance miniature servo valve with just two moving parts. Ideally suited to missile, aircraft and industrial applications, these anti-clogging, 2-stage, 4-way selector valves provide high frequency response and proved reliability even with highly contaminated fluids and under conditions of extreme temperature.

TYPICAL CHARACTERISTICS

Quiescent Flow .... 0.15 gpm
Hysteresis ... 3% of rated current
Frequency Response 3 db @ 100 cps
Supply pressure....500 to 3000 psi
Temperature-Fluid & Ambient −65° F to +275° F
Flow Rate Range ..... .3 to 10 gpm
Weight .... 10.5 ounces

Write for complete data.

Analog Digital Converter



20 Second Synchro

Integrator Tachometer

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

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ond armature form a friction coupling that transmits the limited linear motion of the first disc to the output shaft as a limited angular rotation.

Electrically, the coupling magnet is connected in series with either one of the other electromagnets to a source of 24-volt dc pulses. The two actuating magnets also include a shorted turn that causes a 30 millisec delay which the coupling magnet does not have. The friction coupling therefore operates before the first armature when a signal pulse is applied, and disconnects before the first armature is returned to neutral by the flat springs when the pulse is removed.

This delay in the actuating magnets guarantees complete and exact transmission of the rotary step motion to the output shaft for each input pulse. A new input pulse can be applied as soon as the previous pulse current falls to zero. Up to 10 steps per sec are possible. The rotary motion per step can be adjusted between 1 and 3 deg. Maximum speed is 5 rpm.

FM Motor Controls Alternator Frequency

A frequency-modulated motor (see CtE, May 1959, pp. 106-109) supplied by GM Laboratories, Inc, is used as the error detector in a fine-speed control system built for 400-cps aircraft alternator power supplies by the AiResearch Mfg. Co. of Arizona. These alternators are driven by individual gas turbines to isolate them from the load surges on aircraft propulsion engines. Coarse speed is controlled by a governor on the turbine-alternator shaft which regulates the output of the fuel pump supplying the gas turbine. Fine speed is controlled in this system by a servomotor-driven trim adjustment on the speed governor. The system holds alternator speed to 6,000 rpm plus or minus 6 rpm, thus controlling alternator frequency to 400 cps within 0.1 percent.

The speed control system is shown schematically by Figure 1, which represents the actual governor as a flyball device and the fine trim adjustment as a sliding fulcrum for simplicity. The fine-speed control system compares alternator output frequency to a 400 cps, 0.01 percent reference frequency generated by a tuning fork oscillator. The frequency comparison is made in the FM motor diagrammed in Figure 2. One rotor is driven synchronously by the reference frequency and the other rotor is driven in the opposite direction by the alternator output. When the two frequencies are exactly the same, the output shaft will be stationary, and the output potentiometer will produce a constant signal. When the two frequencies differ, the signal will change as the integral of the error.

The signal from the error detector potentiometer is connected in a bridge circuit with a feedback potentiometer on the governor trim servomotor. Unbalance in this bridge is amplified and used to drive the trim servomotor in the direction to reduce the unbalance by bringing the alternator frequency into correspondence with the reference.

The brake on the FM motor shaft prevents potentiometer change and hence governor trim change during alternator startup.

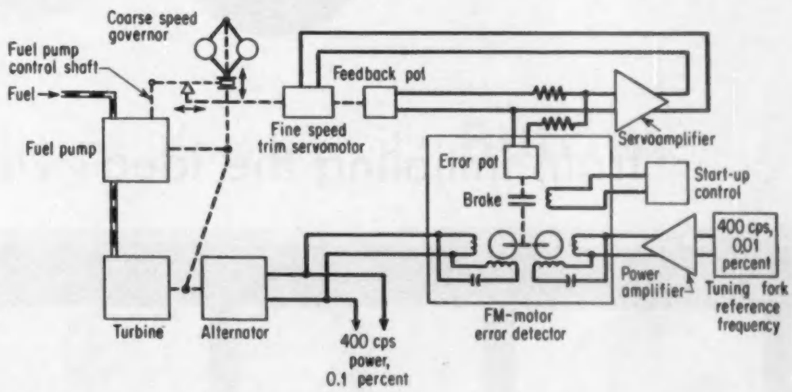


FIG. 1. Aircraft alternator speed control system. Coarse speed control is represented by flyball governor for simplicity. Fine speed control adjusts trim setting on governor by integrating frequency error.

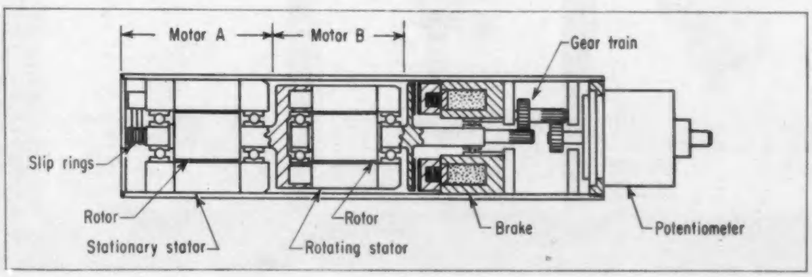
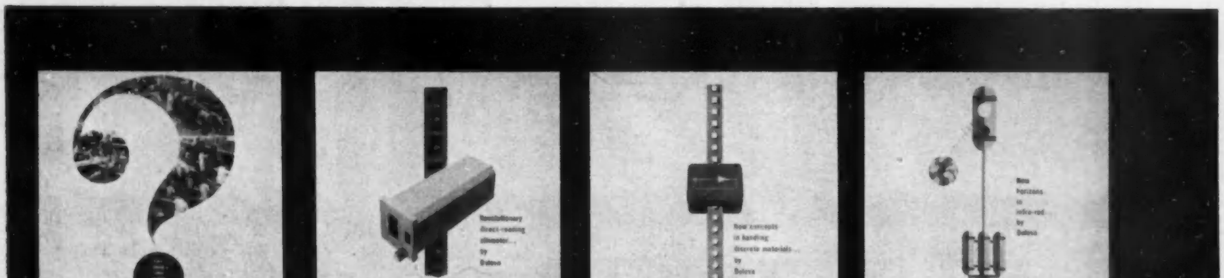
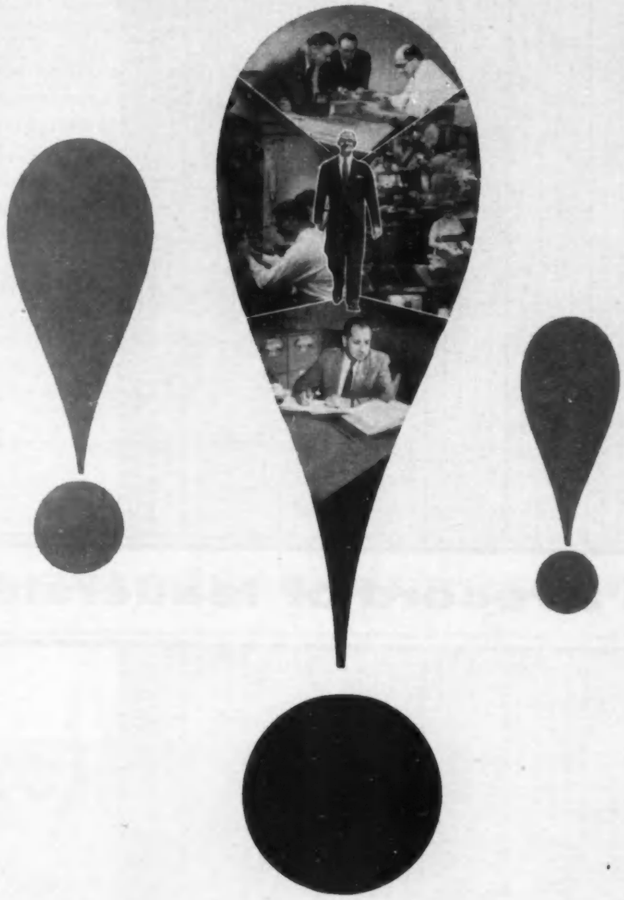


FIG. 2. FM motor used as error detector for fine speed control. Two synchronous motors rotate in opposite directions to produce zero speed on output shaft when alternator frequency matches reference.

from initiating the idea . . . .





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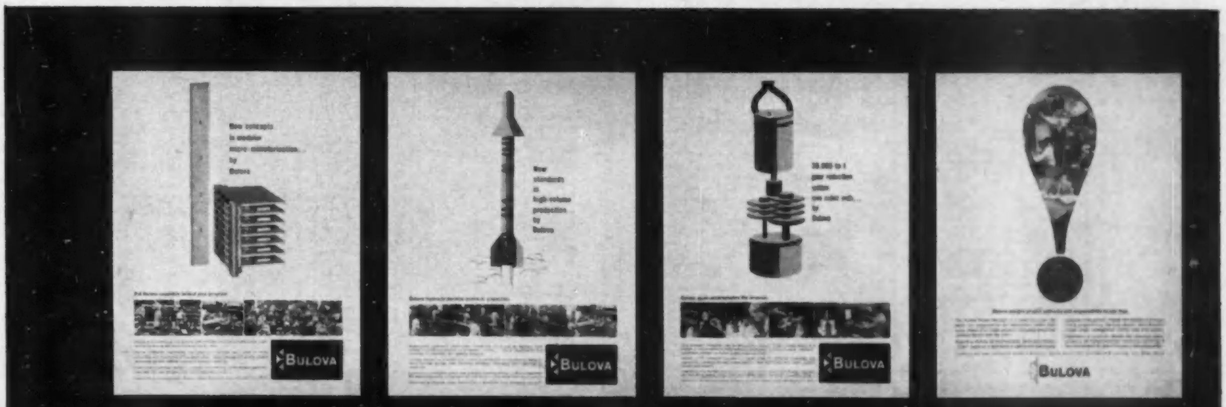
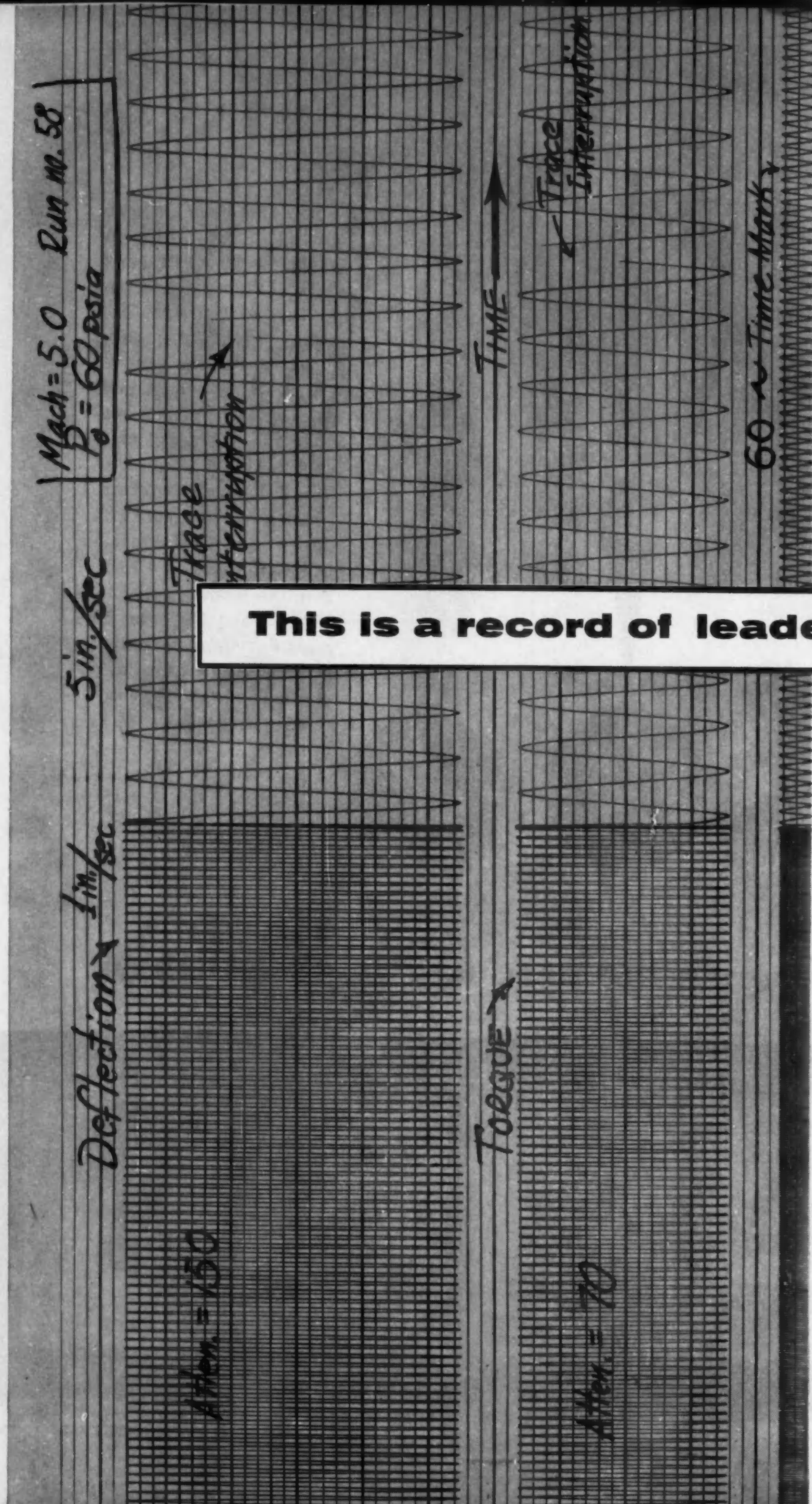


CIRCLE 137 ON READER SERVICE CARD



This is a record of leadership

Honeywell 906A Visicorder record, actual size. Note longitudinal grid lines and trace identification interruptions.

These studies of aerodynamic damping coefficients on an airframe were made by engineers at ARO, Inc. They were conducted in the Gas Dynamics Facility at the U.S.A.F.'s Arnold Engineering Development Center, Tullahoma, Tennessee, wind tunnel center of the Air Research and Development Command.The studies were directly recorded on a Honeywell 906-A Visicorder.

The problem: To measure damping-in-pitch derivatives for a clipped-delta-wing-body configuration over a Mach number range of 2.0 to 5.0 so that these measurements could be compared with the Mach number trend predicted by theory.

The set-up: A model of the delta-wing body, mounted on its cross-flexure pivot support, was forced to oscillate through a linkage by an electro-magnetic shaker. Resistance strain gauges were bonded to the input torque member and to one of the pivot supports. These gauges supplied torque and displacement signals through a carrier amplifier to two galvanometers in the Visicorder. An oscillator, driving a third galvanometer, established a time base for the oscillogram.

The values discovered through this forced-oscillation balance system experiment showed some discrepancies from values predicted by theory, because the theory pertained to simpler bodies than that used in the tests. The experiments provided a new set of data which will result in more accurate predictions for future design.

in aerodynamic research

Z. A. Woodard, Jr., ARO, Incorporated, instrument technician, operates the Visicorder in the measurement of aerodynamic damping coefficients.

The Honeywell Visicorder is the pioneer and unquestioned leader in the field of high-frequency, high-sensitivity direct recording oscillography. In research, development and product testing everywhere, instantly-readable Visicorder records are pointing the way to new advances in product design, rocketry, computing, control, nucleonics . . . in any field where high speed variables are under study.

The new Model 906A Visicorder, now available in 8- and 14-channel models, produces longitudinal grid lines simultaneously with the dynamic traces, time lines, and trace identification by means of new accessory units.

To record high frequency variables—and monitor them as they are recorded—use the Visicorder Oscillograph. Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

Reference Data: Write for Visicorder Bulletin
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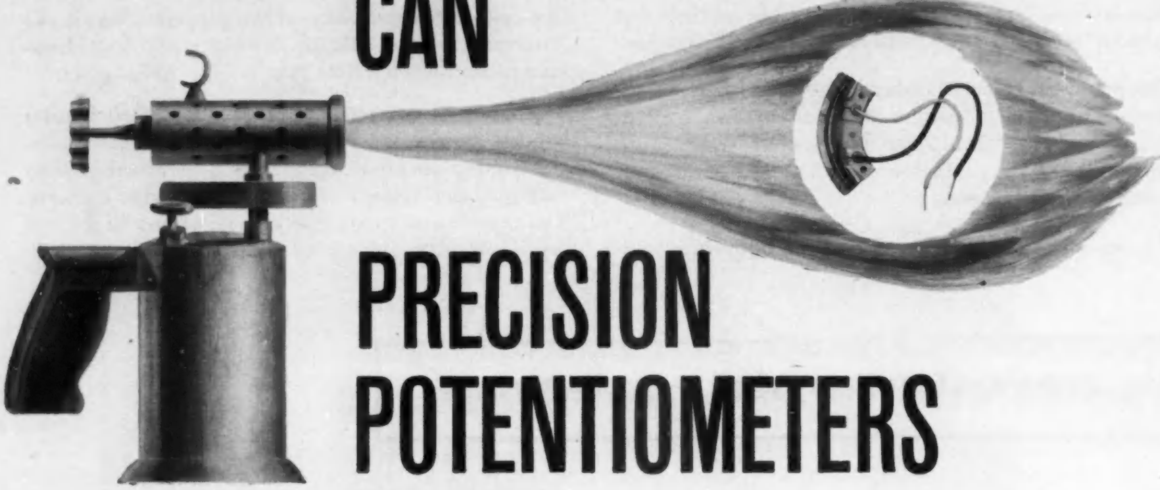
CIRCLE 139 ON READER SERVICE CARD

HOW MUCH HEAT CAN



PRECISION POTENTIOMETERS TAKE?

Special Ketay sector potentiometers have been designed to operate in ambient temperatures up to 500° C.

Ketay precision single-turn, multi-turn, rectilinear and sector potentiometers for control and instrumentation purposes feature compactness and high sensitivity. They are custom engineered for applications once considered too severe because of shock, vibration, torque, resolution or destructive environment.

Potentiometers that meet the most rigid specifications result from:

Creative Engineering—for example, very accurate single-turn ganged potentiometers in size 9 with linearity as fine as 0.15% and 2″ diameter units with linearity as fine as 0.07%.

Superior Materials—selection to give optimum service for particular performance and operational requirements.

Advanced Manufacturing Techniques—such as the ability to weld taps to a single turn of wire as small as 0.0004″ diameter (1/10 the diameter of a human hair).

Ketay potentiometers are being produced in a wide range of types and sizes, from tiny precision pick-offs to complex function and multi-wiper units.

Ketay precision components:
SYNCHROS
RESOLVERS
POTENTIOMETERS
SERVO MOTORS
TACHOMETERS
SERVO AMPLIFIERS
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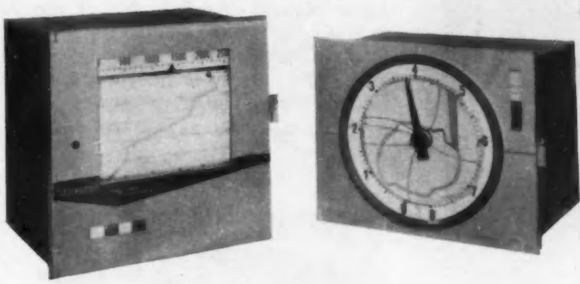
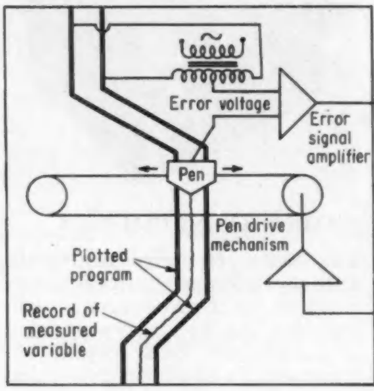
Catalogues available

NORDEN Division of United Aircraft Corporation

KETAY DEPARTMENT, Commack, Long Island, N.Y.

NEW PRODUCTS





NEW CONTROLLER reads program.

Trade named Prekorder, these two new instruments will simultaneously "read" a pencil-drawn program chart, control a process accordingly, and superimpose a record of process performance on the same chart. Process programs appear as double-line graphs, drawn directly on either the strip or circular recording chart.

As shown on the schematic to the left, the two parallel pencil lines that define the program are connected electrically to the ends of a center-tapped transformer winding that serves as a voltage source for an electrostatic field between the lines. The recording pen, serving also as a capacitive probe, picks up an error signal proportional to any deviation from its null position midway between the lines.

Since the pen-probe never touches these lines, the chart on which the lines are drawn may be used as a master program chart, and a clear vellum overlay used to receive the actual recording. System sensitivity may be programmed along with the controlled parameter by merely varying the spacing between the lines. Thus, the spacing can be widened to reduce sensitivity during periods of possible instability and narrowed again where tighter control is required. Pushbutton switches provide six distinct operating modes.—Research, Inc., Hopkins, Minn.

Circle No. 280 on reply card

"PILOT-POSITIONER" combines functions.

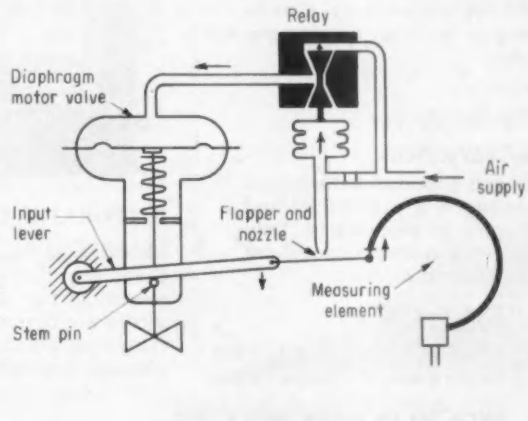
Believed to be the first of its kind on the market, the Pilot-Positioner combines in a single valve-mounted instrument the functions of a pneumatic indicating controller with those of a valve positioner. Its location, close to the process and to the valve it controls, assures minimum transmission lags and a high speed of response.

Basically, the instrument consists of a pneumatic controller modified to provide mechanical feedback from the valve stem through a lever system. The accompanying schematic illustrates its operating principle; the photo, its external appearance. Center dial on the front panel has two pointers; red one indicates setpoint while a black one shows actual value of the measured variable. Smaller dials indicate supply and output pressures. Fourth dial, within the case, gives valve position.—U. S. Gauge Div., American Machine & Metals, Inc., Sellersville, Pa.

Circle No. 281 on reply card

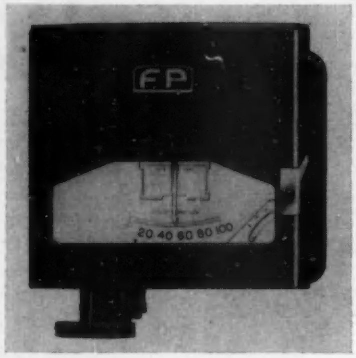
RIGHT: Pilot-Positioner mounted on standard valve

BELOW: Schematic diagram illustrates its operation



NEW PRODUCTS

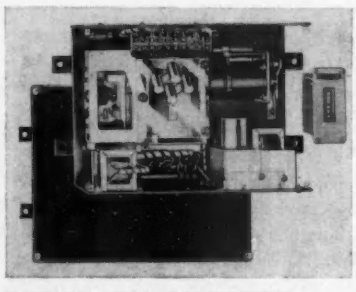
DATA HANDLING & DISPLAY



COMPATIBLE TRANSMITTER

Photo shows F&P's new compatible electronic transmitter, a device which converts motion output from all of the company's flow, pressure, temperature, and level transducers to electrical signals compatible with all miniature electronic instruments. Output may be 1-5 madc into loads of 0-6,000 ohms, 4-20 madc into loads of 0-1,500 ohms, or 10-50 madc into loads of 0-600 ohms. Load may be any value between the limits indicated without requiring additional external resistance. Printed wiring cards facilitate field change. Ambient operation temperatures may range from minus 20 to plus 150 deg F.—Fischer & Porter Co., Hatboro, Pa.

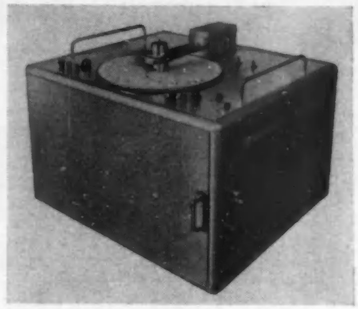
Circle No. 282 on reply card



INTEGRATER-COMPUTER

Identified as the C3A/1 Integrator-Computer, this panel-mounted unit consists of two separately housed assemblies: a computer package and an electromagnetic 6-digit indicator. It is intended primarily for use in Swartwout AutroniC Control Systems, operates from a common 0-0.5 vac signal, and has no effect on the control loop. The square root is extracted by interposing a flyball governor in the servomotor feedback loop. Force exerted by the governor is proportional to the square of its speed. This force positions the core of a differential transformer, thus providing a feedback signal to the servoamplifier input. In a flow integrating system, this signal is compared to the process signal (proportional to the square of the flow rate). Normal counting rate of the indicator is 20,000 counts per day; this can be varied by changing the gear train arrangement.—Swartwout Co., Cleveland, Ohio.

Circle No. 283 on reply card



PLOTS NYQUIST DIAGRAM

This Series 100 Automatic Nyquist Diagram Plotter permits rapid and accurate testing of servo systems. A self-contained transfer function analyzer, it automatically loads Nyquist diagrams with an amplitude error of less than 1 percent and phase angle error of less than 1 deg. Time required for a complete graph is 5 min; this is reduced to 90 sec when the response below 1 cps is not required. Model 103 covers the frequency range from 0.5 cps to 250 cps. Other models extend low frequency range to 0.025 cps. Unit is equally effective with ac or dc electrical servos, and a synchronous mechanical output is available to operate the pilot valve of hydraulic or pneumatic servos.—British Industries Corp., Port Washington, N. Y.

Circle No. 284 on reply card

TAPE PROGRAMMER

A new perforated tape programmer, built to conform to MIL-E-16400, features bi-directional drive, character reading rates up to 200 per sec, and self-contained electronics for control and data playback. Its 6-in. reels will accommodate up to 500 ft of sandwich mylar tape or 300 ft of paper

2 NEW KODAK PAPERS

GIVE YOU WRITING SPEEDS TO 60,000 IPS.

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Kodak Linagraph 44 and 77 Papers cover the whole range of commonly used frequencies and writing speeds and *more*. With them you can record higher frequencies and writing speeds (up to 60,000 ips.) that have been impossible or difficult to record 'til now.

Even over wide amplitudes, sudden beam excursions, or sharp rise times, you get sharp, black traces—traces that are easy to read by visual inspection or on data-reduction equipment, easy to duplicate on diazo-type materials.

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Both new papers have a specially-treated super-strength base that really stands up under processing, handling, rolling, folding, and storage. Extra thin (.0030″) for more footage per given roll diameter. Rolls up to 475 ft. are splice-free. Semi-matte surface readily takes pen or pencil notations.

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KODAK LINAGRAPH 44

relative tungsten speed: 20
thickness: .0030 inches

Orthosensitized on extra-strong paper support, specially designed for recording optimum trace density and contrast from *low* to *moderately high* writing speeds. Can be processed in the CEC Datarite Magazine.

KODAK LINAGRAPH 77

relative tungsten speed: 80
thickness: .0030 inches

The ultimate in high-speed, orthosensitized recording papers. Records *extremely high* writing speeds heretofore considered impractical, yet still retains good trace densities. Covers writing speeds up to 60,000 ips. Because of its wide exposure latitude it records medium-speed traces as well, with excellent clarity. On specially-made rugged, durable paper stock.

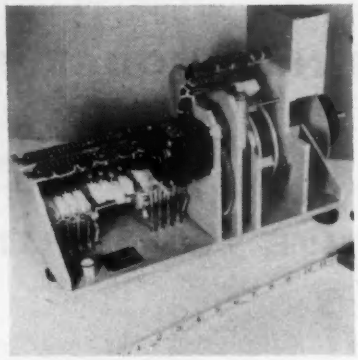
EASTMAN KODAK COMPANY, Rochester 4, N. Y.

Photo Recording Methods Division

Kodak

tape, in widths up to 1 in. The unit weighs approximately 50 lb and requires either a 28-vdc or 115-volt, 400-cycle supply.—Potter Instrument Co., Inc., Plainview, N. Y.

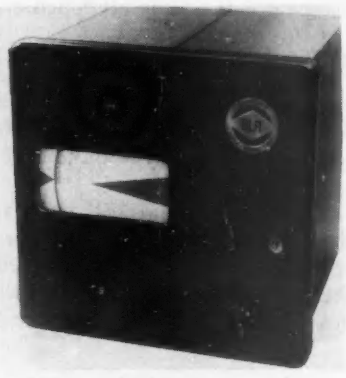
Circle No. 285 on reply card



SIMPLE CODER

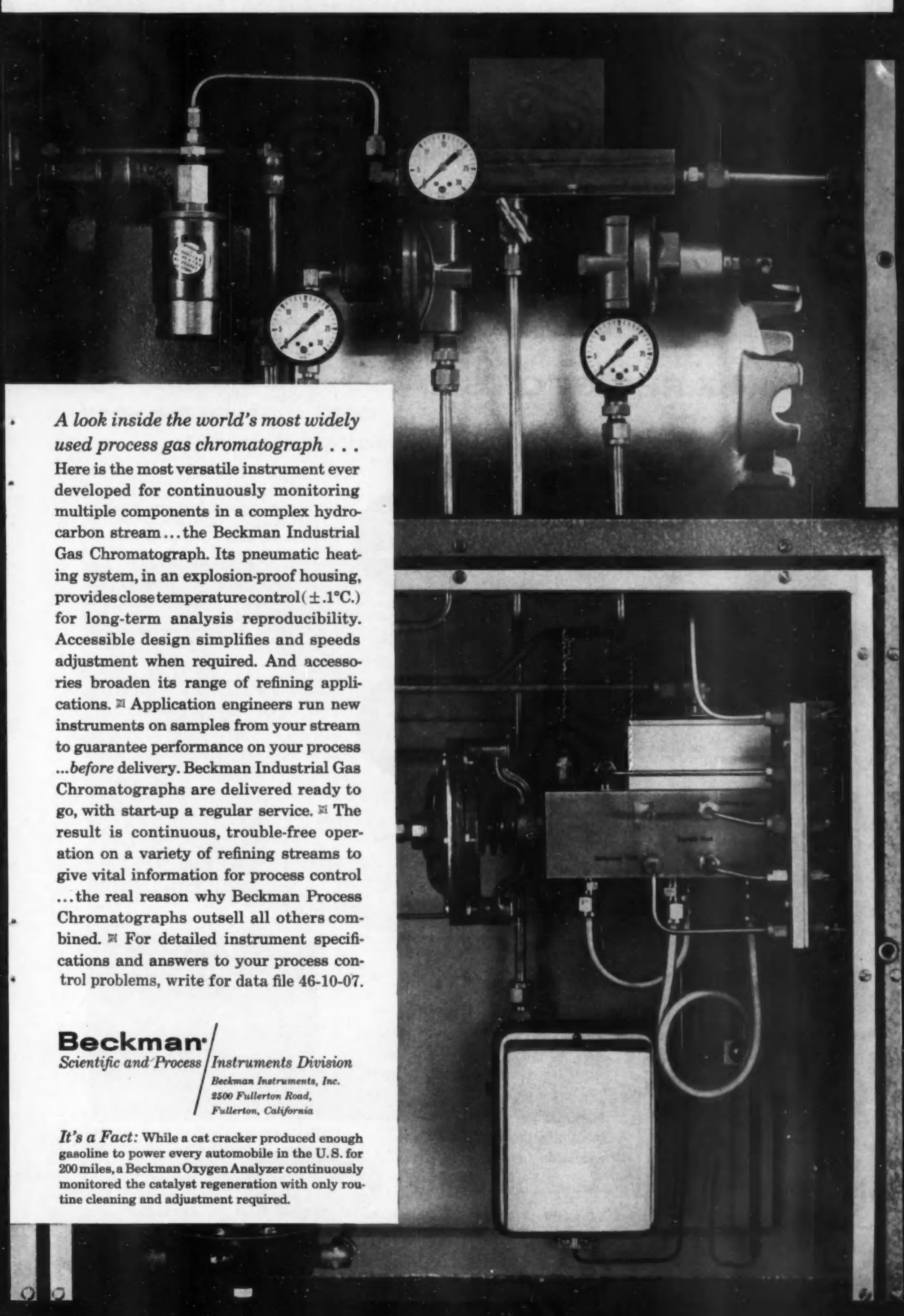
The DynaMetric Model 113 electromechanical coder, shown here, is part of a new telemetering system designed originally for transmitting coded liquid level data over field telephone systems. Suitable for use in a corrosive atmosphere, the encoder consists entirely of standard gear, switch, and relay components. In operation, each increment of liquid level produces a unique set of switch positions. Readings are coded in binary form before transmission.—DynaMetric, Inc., Pasadena, Calif.

Circle No. 286 on reply card



STRAIN INDICATOR

Developed specifically for use in strain gage measurement and control systems, the SR-4 Type 12 Disc Indicator requires less than a square foot of


A look inside the world's most widely used process gas chromatograph . . .
Here is the most versatile instrument ever developed for continuously monitoring multiple components in a complex hydrocarbon stream ... the Beckman Industrial Gas Chromatograph. Its pneumatic heating system, in an explosion-proof housing, provides close temperature control (±.1°C.) for long-term analysis reproducibility. Accessible design simplifies and speeds adjustment when required. And accessories broaden its range of refining applications. ■ Application engineers run new instruments on samples from your stream to guarantee performance on your process ...before delivery. Beckman Industrial Gas Chromatographs are delivered ready to go, with start-up a regular service. ■ The result is continuous, trouble-free operation on a variety of refining streams to give vital information for process control ... the real reason why Beckman Process Chromatographs outsell all others combined. ■ For detailed instrument specifications and answers to your process control problems, write for data file 46-10-07.
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It's a Fact: While a cat cracker produced enough gasoline to power every automobile in the U.S. for 200 miles, a Beckman Oxygen Analyzer continuously monitored the catalyst regeneration with only routine cleaning and adjustment required.

panel area yet retains the accuracy and reading ease of much larger instruments. The device features a large horizontal readout window and a precision engraved dial with 500 graduations. Using a servo-driven slidewire to balance an internal bridge circuit, the Dial Indicator is available in 13 models for a variety of applications. Specified accuracy is within plus or minus 0.15 percent of full scale.—Electronics & Instrumentation Div., Baldwin-Lima-Hamilton Corp., Waltham, Mass.

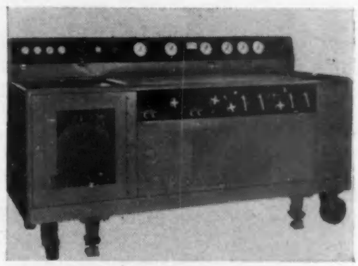
Circle No. 287 on reply card

PLUS . . . .

(288) A compact **dual-servo indicator,** announced by **General Controls Co.,** Glendale, Calif., consists of two independent position servos with digital counter readout and features a static accuracy within 0.1 percent. . . . (289) **Massa Div. of Cohu Electronics, Inc.,** Hingham, Mass., offers a new 12-channel **recording system** with interchangeable plug-in preamplifiers and a choice of 18 pushbutton chart speeds. . . . (290) The Model 524D **electronic counter,** manufactured by **Hewlett-Packard Co.,** Palo Alto, Calif., provides a wide range of frequency and time measurements on a uniform 8-decade numerical readout.

Circle 288, 289, or 290, on reply card

RESEARCH, TEST, & DEVELOPMENT



PNEUMATIC TESTING STAND

Designed to simulate high pressure pneumatic systems, this Model 9887 portable test stand delivers up to 15 cfm of dry air at 100 deg F, under continuously variable pressures from zero to 5,000 psi. Automatically con-

Ten To One

New Fenwal Monitor simultaneously brings 10 remote temperature signals to one central location

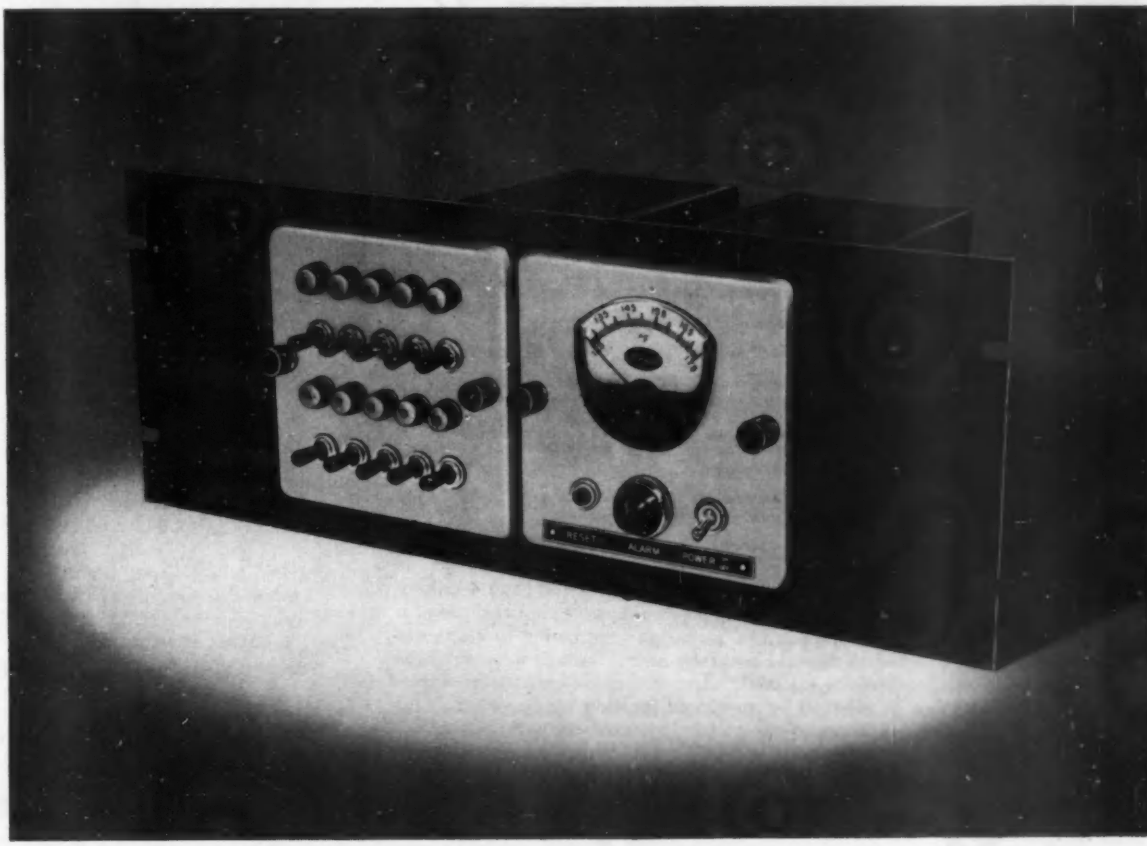
Now there's a monitor that continuously and simultaneously senses all ten of its temperature points. No scanning required . . . no delay in signalling "off" temperatures. *Ten to one it's the positive, fast-acting protection you've needed!*

Monitor's solid-state components are simple, accurate and reliable. Fenwal thermistor sensors install economically with uncompensated electric wiring, have practically limitless life. They change resistance sharply when temperatures change, send strong electrical signals to a rugged, transistorized amplifier. *Wear-free, non-moving parts that combine high performance with low maintenance!*

Fenwal Simultaneous Monitoring Systems are produced by a company with highly integrated design and manufacturing facilities, including its own source of thermistors. And they're repeatedly proving this "better engineering" in all the new commercial jets and many military aircraft. *Small wonder they're dependable on the toughest industrial assignments!*

For complete details or complete engineering of your specific temperature monitoring problem, contact a Fenwal Sales Engineer and write for Catalog. Fenwal Incorporated, 2910 Pleasant Street, Ashland, Mass.

Fenwal Continuous 10-point Monitor indicates one or more "off" temperatures by red light or other signal. Operator merely flicks toggle switches to locate trouble. Dial shows each temperature. Temperature Range: 100°F ranges from −25 to 600°F. Voltage rating: 115/230 VAC.

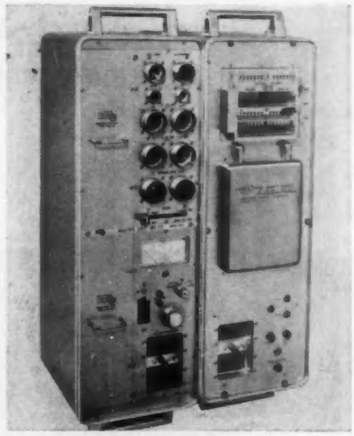


ANOTHER EXAMPLE OF HOW *Fenwal* CONTROLS TEMPERATURE . . . PRECISELY

NEW PRODUCTS

trolled desiccant dryers provide a dew point of minus 40 deg F. Filters remove oil vapor and limit particle size to 25 microns. A 1.5 cu ft receiver stores dry pressurized air. All motor and heater controls, pushbuttons, selector switches, and pilot lights are mounted on the front panel.—George L. Nankervis Co., Detroit, Mich.

Circle No. 291 on reply card



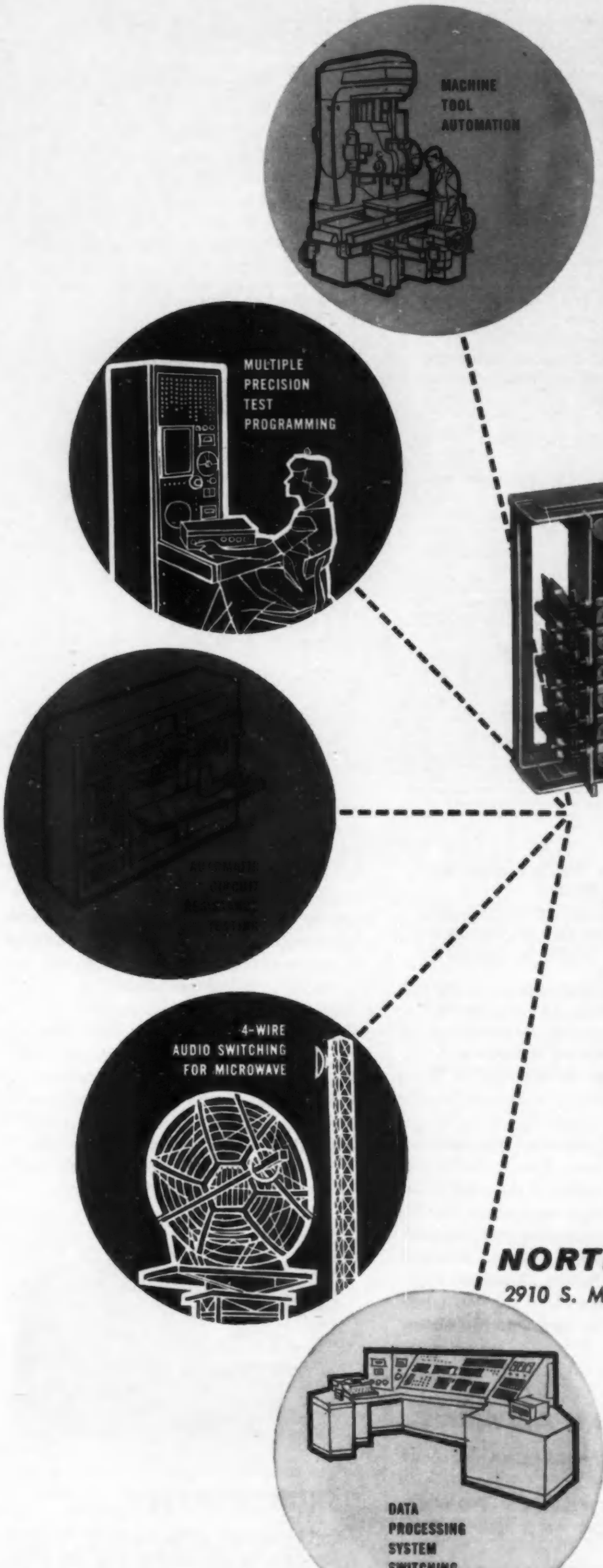
NEW SEISMIC SYSTEM

Complete in two compact, lightweight units, the PMR-20 seismic system is a 24-channel transistorized recording system designed to provide hi-fidelity FM recordings on standard magnetic tapes from the output of standard geophysical amplifiers. A master unit (left in the photo above) contains the modulators, demodulators, and auxiliary electronics. The transport unit houses the recording drum, drive system, and fixed or movable recording heads. Each unit contains its own power supply. System provides an exceptionally high speed-to-noise ratio and a frequency response of from 1 to 500 cps.—Southwestern Industrial Electronics Co., Houston, Tex.

Circle No. 292 on reply card

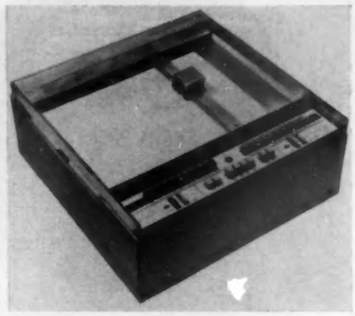
CAPACITANCE STANDARDS

A new line of three-terminal capacitance standards, in both fixed and variable types, has been developed for use in critical measurement of extremely low capacitances. Such devices are relatively free from the effects of capacitance from connecting leads to ground. Values of the fixed units range, in powers of 10, from 0.01 pf


MACHINE
TOOL
AUTOMATION
MULTIPLE
PRECISION
TEST
PROGRAMMING
4-WIRE
AUDIO SWITCHING
FOR MICROWAVE
DATA
PROCESSING
SYSTEM
SWITCHING

to 1,000 pf. Losses in these units are on the order of 10 microradians. Three variable types cover ranges from 0.05-1.1 pf to 50-1100 pf. Fixed units are priced at $45-$60; variable units, at $205-$265.–General Radio Co., West Concord, Mass.

Circle No. 293 on reply card



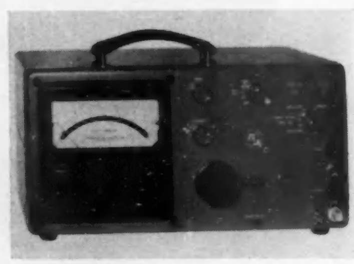
PUSHBUTTON CONTROL

The Librascope X-Y Plotter, Model 210, features pushbutton control of the following: X-Y scales, power on-off, vacuum on-off, plot clear, 4-quadrant plot, reference plot, X-Y reference, continuous trace, and manual plot. Four thumb wheels permit vernier control of the scales and reference axes. The instrument will operate in either a horizontal or vertical position, and accommodates a variety of accessory equipment.

Characteristics:

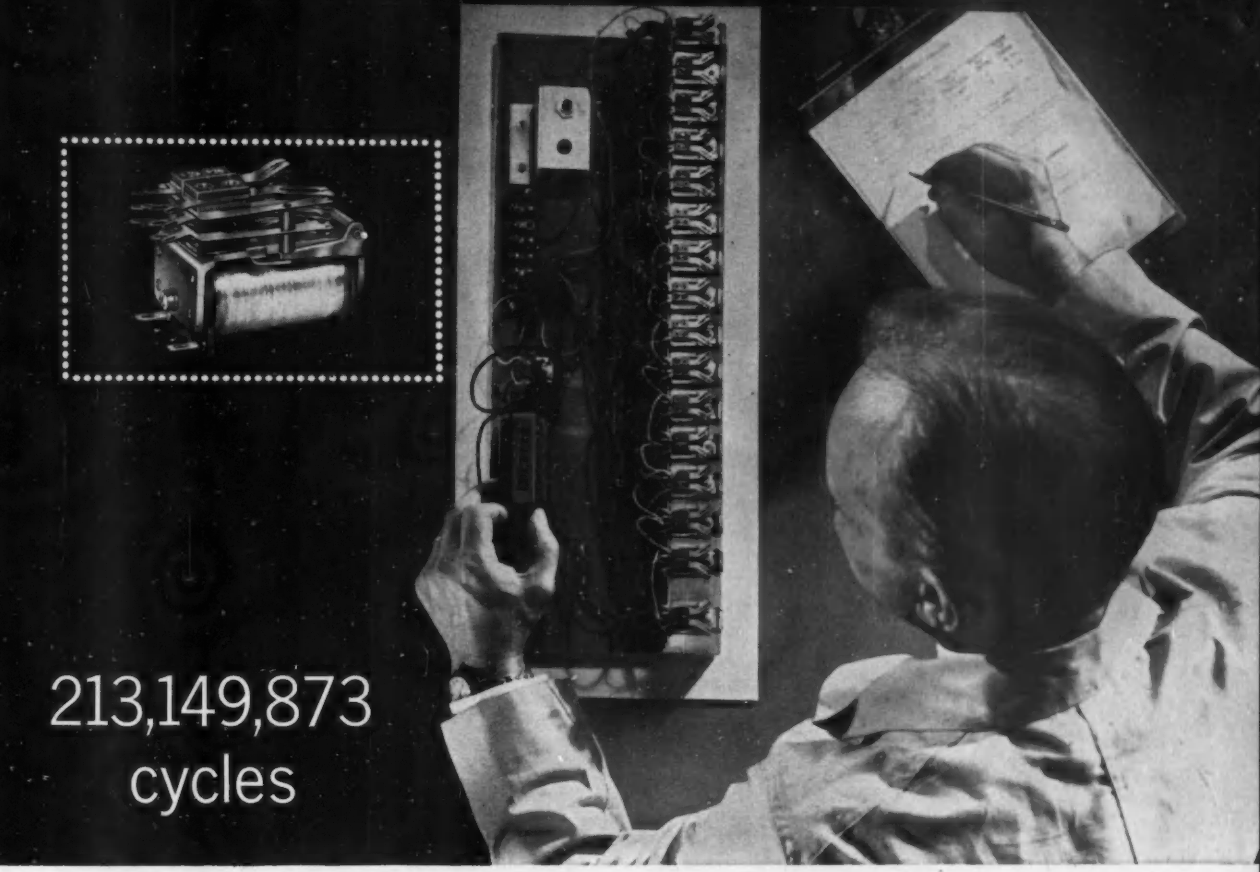
Static error: within 0.1 percent
Dynamic error: within 0.2 percent at 10 in. per sec
Response: 20 in. per sec
Power: 225 watts at 115 volts, 60 cycle
–Librascope, Inc., Glendale, Calif.

Circle No. 294 on reply card



BATTERY-POWERED

Direct currents from 1 $\mu\mu$a to 300 ma full scale in 24 ranges can be accurately measured on this Model 120 battery-powered electronic ammeter.

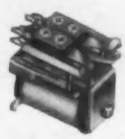


Test proves reliability of P&B's LS telephone type relay

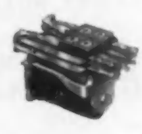
These 16 LS relays, wired into a self-cycling chain, each operated 213,149,873 times before the test was discontinued. This test was made for a nationally prominent manufacturer and the certified results are available upon request.

Here is proof of the inherent reliability of P&B telephone type relays . . . and of the kind of performance you can expect when you specify them. LS relays are available with up to 20 springs (10 per stack) and are adaptable for printed circuit mounting.

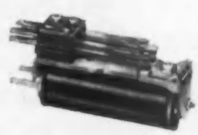
Whenever multiple switching of loads up to 4 amperes is required, the LS can usually meet space, weight and—importantly—price considerations. Get full information today by calling or writing Zeke R. Smith, vice president, Engineering, or contact your nearest P&B representative.



TS RELAY
Short coil relay is available in AC and DC versions. Long life construction. Can be supplied (DC) with up to 20 springs (10 per stack).



GS RELAY
Excellent sensitivity: 50 mw per movable arm minimum (DC). For applications requiring many switching elements in small space.



BS RELAY
Long coil provides high sensitivity (25 mw per movable arm) and room for slugs for pull-in delays (150 milliseconds max.) or drop-out delays (600 milliseconds max.).

LS ENGINEERING DATA

GENERAL:

- **Breakdown Voltage:** 1,000 volts rms 60 cy. min. between all elements.
- **Ambient Temperature:** —55° to +85° C.
- **Weight:** 3 to 4 oz.
- **Dimensions:** 1 5/32" W. x 2 3/8" L. x 1 1/2" H. (4 Form C)
- **Enclosures:** Sealed or dust cover (W can) Sealed or dust cover, up to 6 Form C, single contacts (D can)
- **Mountings:** Four #6-32 tapped holes 3/4" x 5/16" o.c. Other mountings available.

CONTACTS:

- **Arrangements:** 20 springs (10 per stack) max.
- **Material:** 1/16" dia. twin palladium. Other materials available for specific applications.
- **Load:** 4 amps @ 115 volts 60 cy. resistive.

COIL:

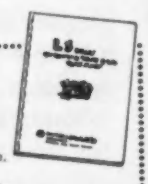
- **Resistance:** 55,000 ohms max.
- **Power:** 65 mw DC per movable standard (50 mw possible); 3.5 watts max. at 25° C.
- **Voltage:** Up to 200 volts DC.

TERMINALS:

- **Contacts:** Three #18 AWG wires.
- **Coil:** Three #20 AWG wires.
- Available with octal plug, taper tabs or printed circuit pins.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

FREE
LS DETERMINATION DATA
Send today for booklet containing certified results of recent test described above. Data includes test circuit, interim and final measurements.

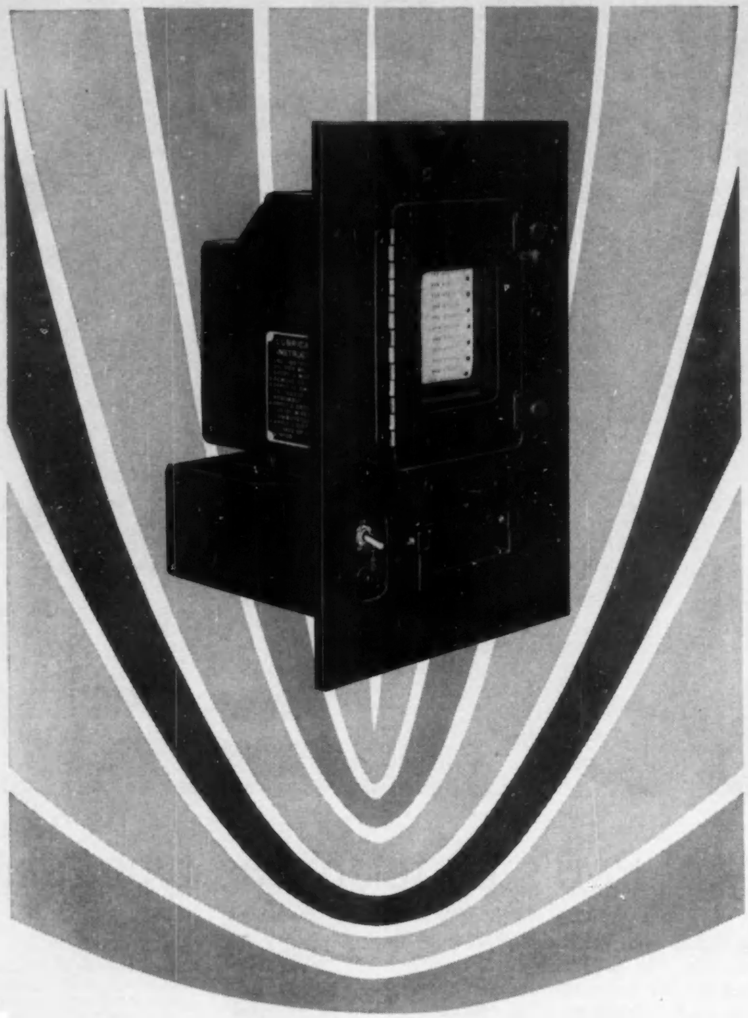


POTTER & BRUMFIELD

DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

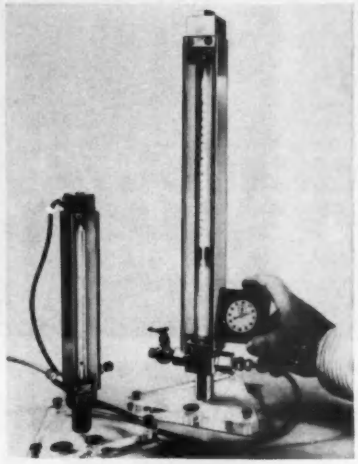
IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

CIRCLE 151 ON READER SERVICE CARD



Indication error is within 1 percent from 1 mμa to 300 ma and within 2 percent from 1 μμa to 300 μμa. Design features include a transistorized meter circuit, low-drift electrometer tube input, feedback with high loop gain, high overload capacity, and a 1,500-hr battery life. Unit weighs 17 lb with batteries and sells for $745.—Belleville-Hexem Corp., Los Gatos, Calif.

Circle No. 295 on reply card



METER CALIBRATOR

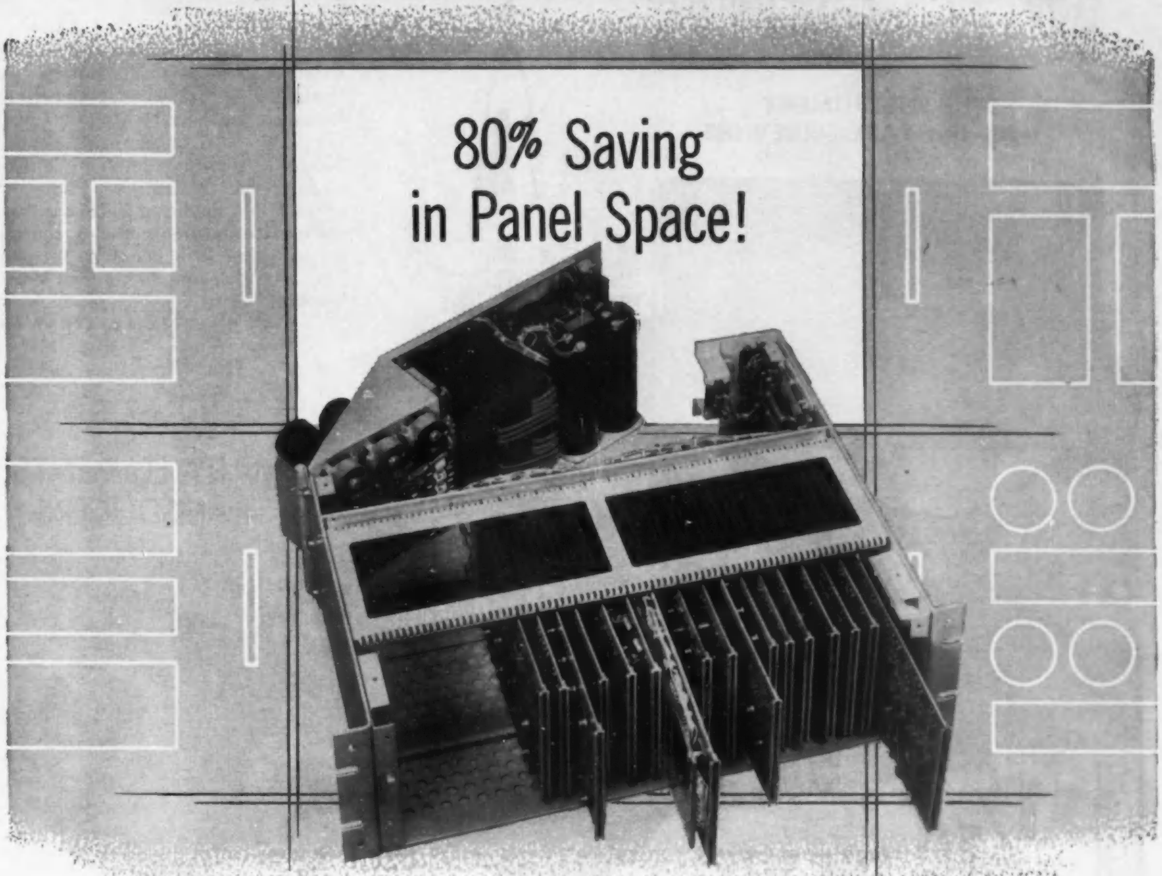
This portable bench model flow rate calibrator permits precision calibration of rotameters and other flow devices in the range of 1 to 5,000 cc per min. A volumetric gas-collecting device, it features a patented, frictionless O-ring seal between its piston and precision bore glass tube. A detachable scale, graduated in cc's, furnishes the volume readings. Photo above shows the unit being used to certify a laboratory rotameter. Accuracy is within 0.2 percent.—Brooks Rotameter Co., Lansdale, Pa.

Circle No. 296 on reply card

PLUS . . .

(297) A new Model T97 **modulation test set** for providing direct frequency and voltage modulation readings on 400-cps systems has just been announced by **Avtron Manufacturing, Inc.**, Cleveland, Ohio. . . . (298) **G. M. Giannini & Co., Inc.**, Pasadena, Calif., now offers a four-channel statistical **acceleration recorder** which indicates the number of times pre-

Magnetic Core Buffer Memory Sets New Design Standards for Data Handling Systems



Requires only 5¼″ of Space in a 19″ Rack

From General Ceramics—Four new magnetic core buffer memories that are setting new design standards among data handling system designers requiring increased efficiency in smaller physical packages.

Now available in either random access or sequential designs:

144 M4A — 144 characters in 9x16 array with a word length of four bits.
144 M8A — 144 characters in 9x16 array with a word length of eight bits.
512 M8A — 512 characters in 16x32 array with a word length of eight bits.
1024 M8A—1024 characters in 32x32 array with a word length of eight bits.

Design Features Include—

1. **SPACE-SAVING**—Require only 5¼″ of standard rack space . . . permit smaller overall system design.
2. **VARIABLE CHARACTER AND BIT LENGTHS**—Unique design of driver circuit permits circuitry of existing data handling system to be enlarged without costly redesign.
3. **HIGHER OPERATING TEMPERATURE RANGE**—Contributes to miniaturized system design because memory functions satisfactorily under higher ambient temperature conditions.
4. **EASE OF MAINTENANCE**—All components are within easy reach. All circuits are on plug-in cards except power supply which is hinged across the back; swings out for easy accessibility.
5. **EXTRA FEATURES**—All units are equipped with an electronic clear and output register at no extra cost.

Complete detailed technical information will be supplied promptly on request. Please address inquiries to Dept. CE.

GENERAL CERAMICS
ORIGINATOR OF THE SQUARE LOOP FERRITE

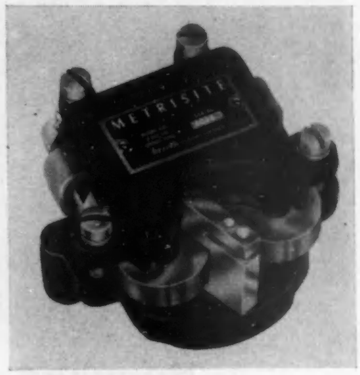
Applied Logics Division
GENERAL CERAMICS CORPORATION
KEASBEY, NEW JERSEY, U.S.A.

CIRCLE 153 ON READER SERVICE CARD

scribed levels of acceleration are reached. . . . (299) Developed by **Remanco, Inc.**, Santa Monica, Calif., the RP-175 **target simulator** permits complete dynamic tests of missile tracking radar systems. . . . (300) A combination **discharge gauge and two-station thermocouple gauge control,** for measuring extremely high vacuum, was recently announced by **Veeco Vacuum Corp.,** New Hyde Park, N. Y.

Circle No. 297, 298, 299 or 300 on reply card

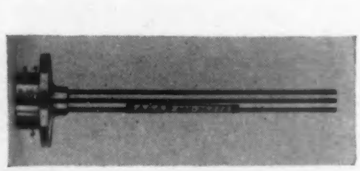
PRIMARY ELEMENTS & TRANSDUCERS



MOTION PICKUP

Called a "Metrisite", this motion sensing device features extreme resolution, high output voltage, excellent linearity, and rugged construction. Units now in production will measure either angular or linear movements. Sizes may range from subminiature models to models capable of measuring over 4 in. of linear motion.—Brush Instruments Div., Clevite Corp., Cleveland, Ohio.

Circle No. 301 on reply card



ELECTRICAL PLUMB-BOB

Used to check the vertical alignment of missiles prior to launching, this small, lightweight sensor consists of an iron pendulum suspended in a

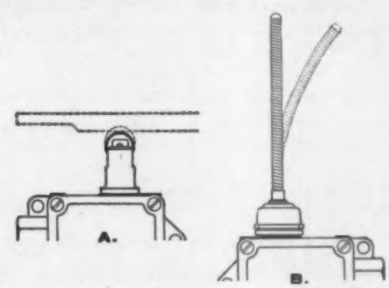
These high-capacity "BAF1" switches seal out dust, oil, and moisture

MICRO SWITCH "BAF1" enclosed switches are protected from physical damage by sturdy aluminum cases, and from oil, dust, dirt, and water by an O-ring seal between the case and the cover plate, and an elastomer boot around the plunger. Mounting holes accept ¼-inch bolts.

These high-capacity switches make and break steady state currents of 20 amperes and switch inrush currents as high as 75 amperes. The "BAF1" Series is especially suitable for heavy-duty industrial applications.

"BAF1" switches have single-pole double-throw contact arrangements. The switches may be used either normally-open or normally-closed. Available in either left hand or right hand mounting designs.

Consult the Yellow Pages for the name of the distributor near you. Send for Catalog 83.



Sealed roller plunger actuator (A) can be adjusted horizontally through 360° permitting operation from any direction. Actuator shaft is protected by internal O-ring seal. Flexible coil spring actuator (B) can be operated from any angle except direct pull.

Underwriter's Laboratories listing: 20 amps, 125, 250, or 460 vac; ½ amp, 125 vdc; ¼ amp, 250 vdc; 1 hp, 115 vac; 2 hp, 230 vac; 10 amps, 125 volts when controlling tungsten filament lamp loads on a-c circuits.

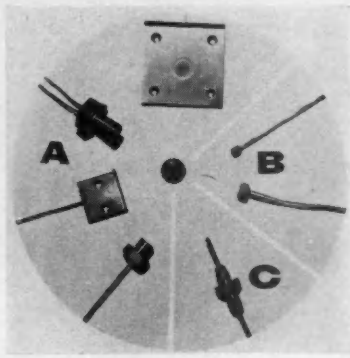
MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
In Canada: Honeywell Controls Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

CIRCLE 155 ON READER SERVICE CARD

fluid filled tube. Miniature coils at the bottom of the tube are spaced 90 deg apart and form magnetic pickups which detect any deviation of the pendulum from a vertical position. Accuracy of the device is said to be within three min of arc. It weighs 2.5 oz and has an over all length of less than 5 in.–Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N. J.

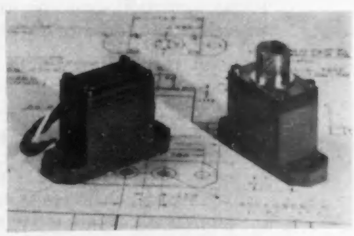
Circle No. 302 on reply card



SPECIAL T'COUPLES

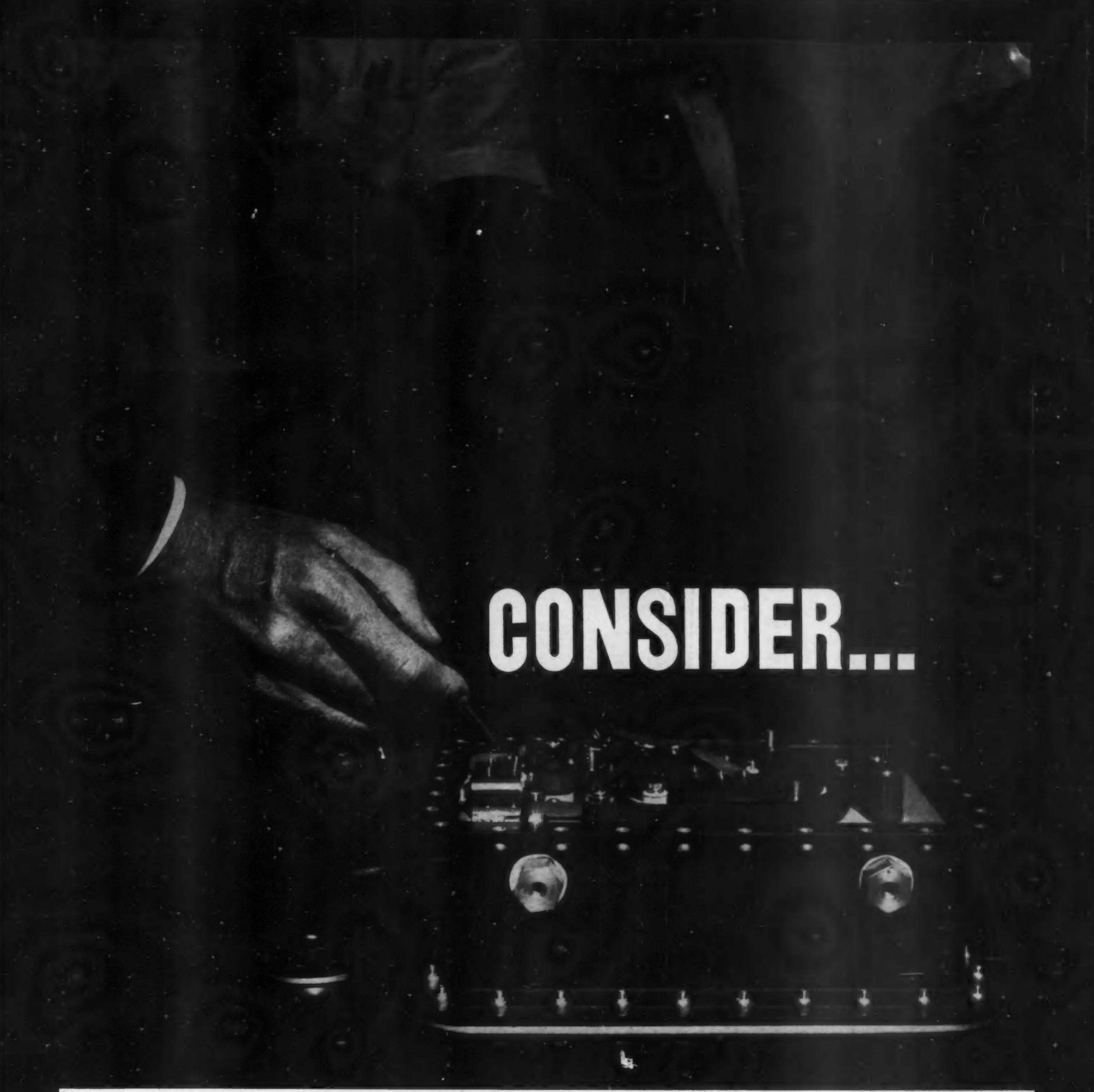
Photo above illustrates some of the special designs of a new line of thermocouples for immersion, heat transfer, and surface temperature measurements required in missile and rocket engine testing. Units cover ranges from minus 350 to plus 2,000 deg F, and are calibrated at two points. On the heat transfer types, the junction is accurately positioned at a fixed distance from the surface. The immersion types feature an average response time of less than 250 msec and have been hydrostatically tested to 5,000 psi.–Astra Technical Instrument Corp., South Pasadena, Calif.

Circle No. 303 on reply card



RATINGS TO 5,000 PSID

Small, but rugged, these two new differential pressure transducers are well-suited for missile and rocket hydraulic



Lockheed's endless-loop tape recorders

DEVELOPED FOR SPACE COMMUNICATIONS, the recording capabilities of Lockheed's new endless-loop tape recorders are creating interest wherever the need exists for stored data in a critical environment. The original design is now operational in delayed and continuous recording and playback of stored data. Its endless-loop mechanism records and plays back in the same direction of tape travel . . . without rewind.

Variations of this lightweight, small size, low power consumption unit are available in a wide range of tape speeds and multiplicity of tracks. For more information on advanced recording techniques to meet your recording needs, write Marketing Branch, Lockheed Electronics and Avionics Division, 6201 East Randolph Street, Los Angeles 22, California.

Look to Lockheed for LEAD*ership in Electronics*

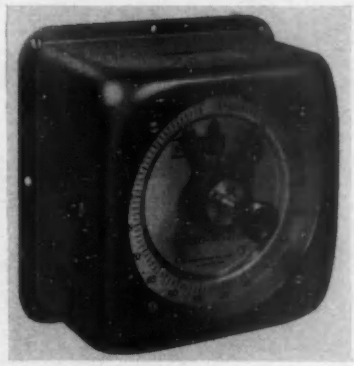
LOCKHEED ELECTRONICS & AVIONICS DIVISION

REQUIREMENTS EXIST FOR STAFF AND SUPERVISORY ENGINEERS

system applications where both space and weight are critical factors. Both units use two half-bridge SP2 strain elements connected in a full bridge with all active legs. Pressure ratings are from 0-100 through 0-5,000 psid. Sensitivity ranges from 2 to 4 mv per volt, and compensation can hold the thermal zero shift to less than plus or minus 0.01 percent of full scale per deg F. Combined nonlinearity and hysteresis error is less than 1 percent. —Standard Controls, Inc., Seattle, Wash.

Circle No. 304 on reply card

CONTROLLERS, SWITCHES, & RELAYS



PRESET COUNTER

Called the Cyclo-Master, this new preset counter and controller offers three optional operating modes: one-count switching, one-cycle switching, and differential (add and subtract) counting and switching. The electrically operated unit counts at speeds up to 1,000 counts per min, and may be preset to any cycle from 1 to 100 counts. It will recycle without pause between successive cycles. Control circuit consists of an spdt relay switch rated to handle a 10-amp, 115-volt noninductive load.—Counter and Control Corp., Milwaukee, Wis.

Circle No. 305 on reply card

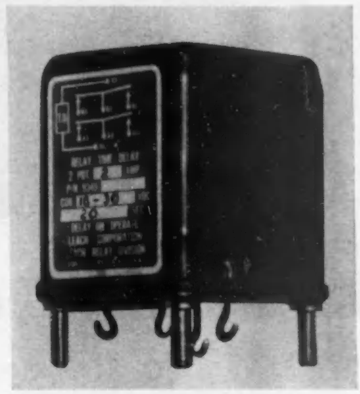
FOR HEATING & COOLING

Two new self-contained, self-operated temperature regulators have been designed specifically for heating and cooling services. Designated as Class

NEW PRODUCTS

M (direct-acting) for heating service and Class MR (reverse-acting) for cooling service, they are available in ¾- and 1-in. body sizes. New design includes a unique balancing bellows that permits smooth operation at inlet pressures and pressure drops up to 100 psi. Units will accommodate a wide variety of interchangeable sensing elements with various ranges, spans, and bulb materials.—Leslie Co., Lyndhurst, N. J.

Circle No. 306 on reply card



FOR MISSILE CONTROLS

Two new miniature transistorized time delay relays have been designed to provide greater reliability and to satisfy the minimum requirements of MIL-R-6106C. Suitable for a variety of remote control applications in guided or ballistic missiles, they are available with time delay on pickup or time delay on dropout. Prespecified delays range from 0.1 sec to 3 min.

Characteristics:

Temperature range: minus 55 to plus 120 deg C
Operating voltage range: 18 to 30 vdc
Contact rating: 2 amp resistive
Weight: 0:35 lb
Volume: under 4.5 cu in.
Vibration: 2,000 cps at 20 g
—Leach Corp., Los Angeles, Calif.

Circle No. 307 on reply card

PLUS . . .

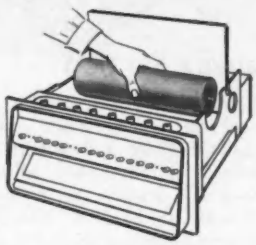
(308) **Square D Co.,** Milwaukee, Wis. has added a new mechanically held **dc relay** to their line of Type D relays for pilot control. . . . (309) To precisely indicate Mach numbers or pressure ratios, **Aero Mechanism, Inc.,** Van Nuys, California, is offering a

These features of

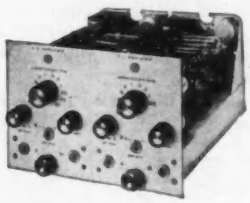
<u>new</u> Brush ultralinear recording systems...

. . . give you more <u>application</u> <u>versatility</u>!

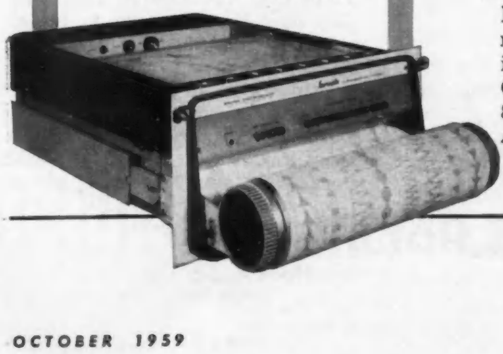
Simplified Chart Re-loading.



Interchangeable, plug-in signal conditioners.



Positive Chart Take-up Drive.



In the fields of telemetry, ground support systems, analog computing and laboratory testing, Brush recording systems have incorporated features which have consistently kept ahead of engineering requirements. Here are a few that show why—

INTERCHANGEABLE PLUG-IN SIGNAL CONDITIONERS. You get your *choice of sensitivities*—you get high input impedance—zero suppression.

SIMPLIFIED FAST CHART RE-LOADING. Loaded from the top—features automatic alignment and tracking.

ACCURATE, EASILY REPRODUCIBLE RECORDINGS. Your choice of rectilinear or curvilinear charts—rugged "throw-proof" pens.

Illustrated above is a Brush RD-1684 rectilinear, 8 channel recording system. Sensitivity of 10 millivolts per chart line—input impedance, 10 megs balanced or 5 megs grounded. Complete system includes mobile cabinet, oscillograph and 8 signal conditioners. No additional preamplifiers required. Available from stock.

brush INSTRUMENTS

DIVISION OF

37th & PERKINS **CLEVITE** CORPORATION CLEVELAND 14, OHIO

compact **hermetically-sealed** switch with a static volume of less than 0.2 cu in. . . . (310) **C. P. Clare & Co.**, Chicago, Ill., has developed a **flat pack relay** which contains six switches and a single operating coil.

Circle No. 308, 309, or 310 on reply card

POWER SUPPLIES

MISSILE BATTERY

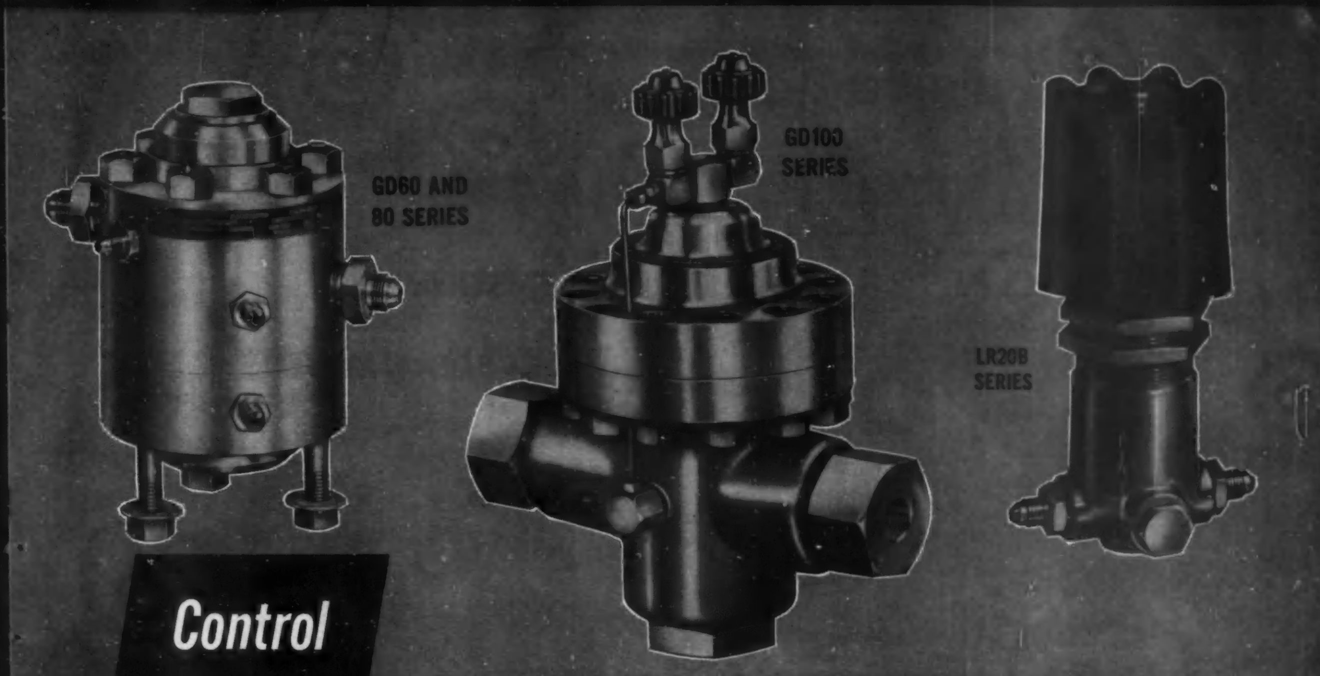
Capable of providing six times more electrical energy than batteries of equivalent size and weight, this new automatically-activated Silvercel primary can delivery up to 350 amp at 28 volts for 11 min. This represents 31 watt-hours per lb or 1.7 watt-hours per cu in. Developed for use in missile systems, this battery has a shelf life, in the dry condition, of about 5 years; in the activated condition, about 8 hours.—Yardley Electric Corp., New York, N. Y.

Circle No. 311 on reply card

PROGRAMMABLE POWER

Three new transistorized power supplies have been designed to furnish precise, well regulated voltages from a programmed source such as a tape or card reader. In addition, pushbutton panels permit manual selection. Output ranges for the three models are as follows: 6 to 36 vdc in 0.1-volt steps at 30 amp; 1 to 500 vdc in 1-volt steps at 1 amp; and 0 to 99.9 vdc in 0.1-volt steps at 1.5 amp.—Southwestern Industrial Electronics Co., Houston, Tex.

Circle No. 312 on reply card



Control gases safely, accurately

TO 15,000 PSI AND 50,000 SCFM WITH

VICTOR REGULATORS

You get precise regulation of high pressure gases with large flow rates, because Victor employs gas pressure to control the regulating diaphragm. The result is accurate delivery from 5 to 15,000 psi with inlet pressures to 15,000 psi . . . plus ability to obtain flows in excess of 50,000 scfm at maximum inlet and outlet pressures. Chart below shows operating range of standard models.

MODEL NO.	MAX. INLET PSI	MAX. OUTLET PSI	FEATURES	MAX. FLOW SCFM
GD10	3,600	500	Single adjustment regulator control	250
GD30	2,500	2,500	Load & bleed valve control	400
GD31	3,600	3,600	Load & bleed valve control	600
GD61C	2,500	2,500	Load & bleed valve control	170
GD62C	3,600	3,600	Load & bleed valve control	200
GD65	6,000	6,000	Load & bleed valve control	250
GD65C	7,000	7,000	Load & bleed valve control	250
GD80A	5,000	5,000	Load & bleed valve control	500
GD81A	10,000	10,000	Load & bleed valve control	800
GD86R	10,000	10,000	For remote control only	1,200
GD100R	6,000	6,000	For remote control only	20,000
GD100	6,000	6,000	Load & bleed valve control	20,000
GD200	6,000	6,000	Load & bleed valve control	50,000
GD700	7,000	7,000	Single adjustment regulator control; self relieving	250
SR10	3,600	1,000	Small, spring loaded regulator	4
LR20B	7,000	7,000	Spring loaded regulator; self relieving	2
LR20BSS	10,000	10,000	Spring loaded; stainless steel	2
LV10	7,000	7,000	Loader valve control	15
BPR10	7,000	7,000	Back pressure regulator	2

Operating temperature range: $-67°$F. to $+250°$F.

. . . Yours for the asking
Take advantage of Victor's long experience with high pressure gas regulation to help solve your special problems involving flow rates, delivery pressures, corrosive fluids and temperature compensation. Write, wire or phone us today. No obligation.

All models listed are field proved. Most are designed for panel mounting or remote control. They regulate all non-corrosive gases, including oxygen. Stainless steel models available for corrosive gases and pressures above 10,000 psi. For complete specifications, write for Victor High Pressure Regulator sheets.

VICTOR® for regulators

VICTOR EQUIPMENT COMPANY MISSILE DIVISION

Mfrs. of High Pressure and Large Volume Gas Regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

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J. C. Menzies & Co., Wholly-Owned Subsidiary

CIRCLE 163 ON READER SERVICE CARD

FRICTION ELIMINATED TO ACHIEVE

the Ultimate in Performance

FOR SPRING RESTRAINED ACCELEROMETERS

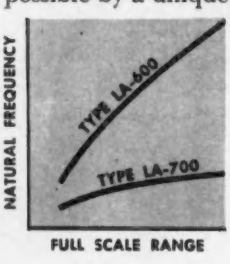
TYPE LA-600
shown actual size

- Full Scale Range: ±1 to ±40 G
- Full Scale Output: to 25 volts
- Threshold-Resolution: 0.0001 G
- Damping Ratio: 0.6 ±.2 typical from −65°F to +250°F
- Natural Frequency: 16 to 100 cps
- Cross-Axis Sensitivity: 0.005 G per G maximum
- Shock: to 60 G
- Vibration: 10 G to 2000 cps
- Size: 1 7/8" diameter, 2 3/8" long
- Weight: 1.2 lbs. maximum

TYPE LA-700
shown actual size

- Full Scale Range: ±1 to ±60 G
- Full Scale Output: to 25 volts
- Threshold-Resolution: 0.0001 G
- Damping Ratio: 0.6 at 25°C typical
- Natural Frequency: 5 to 30 cps
- Cross-Axis Sensitivity: 0.005 G per G maximum
- Shock: to 100 G
- Vibration: 15 G to 2000 cps
- Size: 2 1/32" diameter, 2 7/16" long
- Weight: 1.2 lbs. maximum

The virtual elimination of friction in both these new Honeywell linear accelerometers is made possible by a unique web spring suspension. This feature combined with an electro-magnetic pick-off permits resolutions of extremely low level inputs.



These two instruments span the entire range of dynamic performance.

The LA-600 with its magnetic damping is used for higher natural frequency applications. The LA-700 with its compensated fluid damping is designed for lower natural frequency applications. Write for Bulletins LA-600 and LA-700 to Minneapolis-Honeywell, Boston Division, 40 Life Street, Boston 35, Mass.

Honeywell

H *Military Products Group*

IMPORTANT: Circle key numbers below and mail before January 1, 1960

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
9	19	29	39	49	59	69	79	89	99	109	119	129	139	149	159	169	179	189	199

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201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
204	214	224	234	244	254	264	274	284	294	304	314	324	334	344	354	364	374	384	394
205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

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4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
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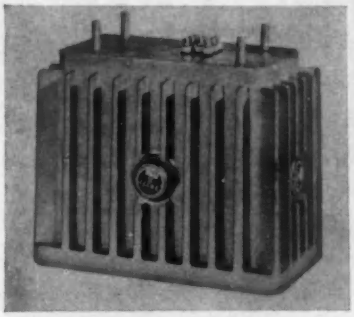


CLEAN DESIGN

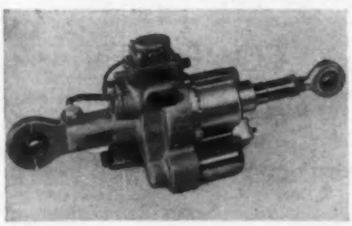
Each side of this cast, finned housing serves as a heat sink for one of four power transistors. This arrangement permits the use of lower-cost germanium transducers, without sacrificing output power. Epoxy compound used to seal most of the internal components has a heavy slate content for more effective heat conduction.

Characteristics:

Output: 12 volts at 0 to 3 amp
Regulation: within 0.1 percent
Ripple: 2 mv peak-to-peak
Dimensions: 4½x7x6 in.
Weight: approximately 6 lb
—Mid-Eastern Electronics, Inc., Springfield, N. J.

Circle No. 313 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

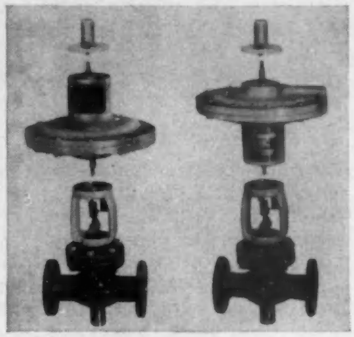


CUSTOM DESIGN

The Series 17 Servoactuators are integrated hydraulic packages designed for missile and aircraft control systems. Units include: electrohydraulic servovalve, a cylinder-piston assembly, and an electrical feedback device. Optional devices, such as pressure or flow limiters, snubbers, piston locks,

solenoids, and integral filters, may be added for special applications. Typical models operate at temperatures up to 350 deg F; special models can be designed for higher temperatures.—Moog Servocontrols, Inc., East Aurora, N. Y.

Circle No. 314 on reply card



REVERSIBLE OPERATOR

Newest addition to the "Bantam" line of control valves is the versatile 540 Series. This unique series features a single operator which permits either normally-open or normally-closed operation. As shown in the photo above, simple inversion of the operator provides the change. Valves feature Teflon packing and gaskets, a body temperature rating of 450 deg F, and flow coefficients from 0.002 to 13.2. Cast aluminum operator uses a 3 to 15 psi-air signal on a molded diaphragm and exhibits low hysteresis and linear response.—George W. Dahl Co., Inc., Bristol, R. I.

Circle No. 315 on reply card

COMPONENT PARTS

NULLING AMPLIFIERS

The Pennon Series 2200 miniature magnetic servo nulling amplifiers are compatible with either silicon or germanium transistor drive circuits, exhibit a 12-msec response time, and will withstand high line transients without damage. Outputs range from 3 to 16 watts; weights, from 5 to 10 oz.—Pennon Electronics, Inc., Bell Gardens, Calif.

Circle No. 316 on reply card

TYPE 321

TRULY PORTABLE

- Battery Powered.
- Weighs only 13½ lbs. without batteries. Batteries weigh 2 to 4 lbs.
- Size only 5¾" x 8¼" x 16".

HIGH PERFORMANCE

- Vertical Response: DC to 5 MC, 0.07 μsec risetime.
- Calibrated Sensitivity: 0.01 v/div to 20 v/div in 11 calibrated steps. Continuously adjustable from 0.01 v/div to 50 v/div.
- Calibrated Sweeps: 0.5 μsec/div to 0.5 sec/div in 19 calibrated steps. Accurate 5x magnifier extends calibrated range to 0.1 μsec/div. Continuously adjustable from 0.1 μsec/div to 1 sec/div.
- Simplified Triggering: Fully automatic, or amplitude-level selection with preset stability control.
- 4-KV Accelerating Potential on 3" crt.
- 6-div by 10-div Display Area.
- Amplitude Calibrator.

NO POWER SOURCE PROBLEMS

Operates from:

1. Ten size D Flashlight cells, ½ hour continuous, more with intermittent, operation.
2. Ten rechargeable cells, 2.5AH—3 hours continuous operation. Ten rechargeable cells, 4.3AH—5 hours continuous operation.
3. 11 to 35 v dc (aircraft, auto, boat, etc.).
4. 105 to 125 v ac or 210 to 250 v ac, 50 to 800 cps.

Price	**$775.00**
Built-in Battery Charger	**35.00**
Complete Set of 2.5AH Batteries	**36.50**

f.o.b. factory

It's so easy to take the Type 321 wherever an oscilloscope is useful. It's a convenient solution to many difficult situations, too ... for example: Where power cords are apt to be a nuisance—where isolation from ground is desirable—where power-line fluctuations are troublesome—where hum pick-up is a problem. The Type 321 is sure to satisfy your portable oscilloscope needs.

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TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics, Portland, Oregon, Seattle, Wash.; Hytronic Measurements, Denver, Colo., Salt Lake City, Utah.

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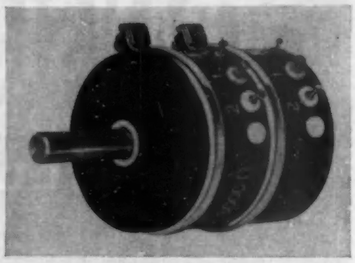
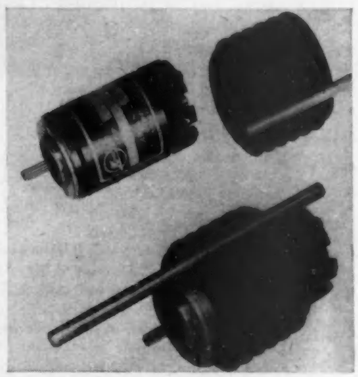
If you missed the Type 321 at WESCON, see it at NEC, booth 193-194.



SERVO-MOUNTING POT

Built for heavy duty service in servo applications, this 3.5 watt precision wire-wound pot can be supplied in resistance values up to 100 K. Model 176 meets the low-torque requirements of nearly all servo applications with less than 0.5 oz-in. per section in standard construction. Other features include: a temperature range of minus 55 to plus 105 deg C, insulation resistances of 100,000 megohms, and a life span up to 5 million revolutions. Units meet or exceed the requirements of JAN-R-19 and MIL-5272A.—New England Instrument Co., Woonsocket, R. I.

Circle No. 317 on reply card

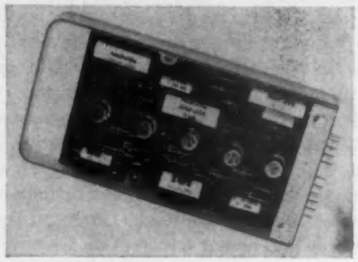


UPS TEMPERATURE LIMIT

Designed to increase the maximum operating temperature of rotary components, a new line of heat dissipating coils features low-cost and rapid mounting. Photo above illustrates an assembly. Coils consist of deeply threaded aluminum tubes with bores slightly smaller than the component OD's. A lengthwise slot permits insertion of a spreader bar that holds the coil open until the motor, synchro, or other component is positioned. When the spreader bar is removed, spring tension of the coil provides intimate contact with the

component to be cooled.—Kearfott Co., Inc., Clifton, N. J.

Circle No. 318 on reply card



PLUG-IN AMPLIFIERS

This Model S-10001-P germanium transistor plug-in module is one of four new ac amplifiers featuring high gain and low noise. Units are designed for use in rack mounting frames and other modular hardware.

Characteristics:

Gains: 300 or 1,000
Frequency response: flat from 60 cps to 10 kc or 1 kc to 30 kc
Input impedance: greater than 50 K
Temperature range: 32 to 140 deg F, with little change in gain
—Plug-In Instruments, Inc., Nashville, Tenn.

Circle No. 319 on reply card

NEW CABLE LINE

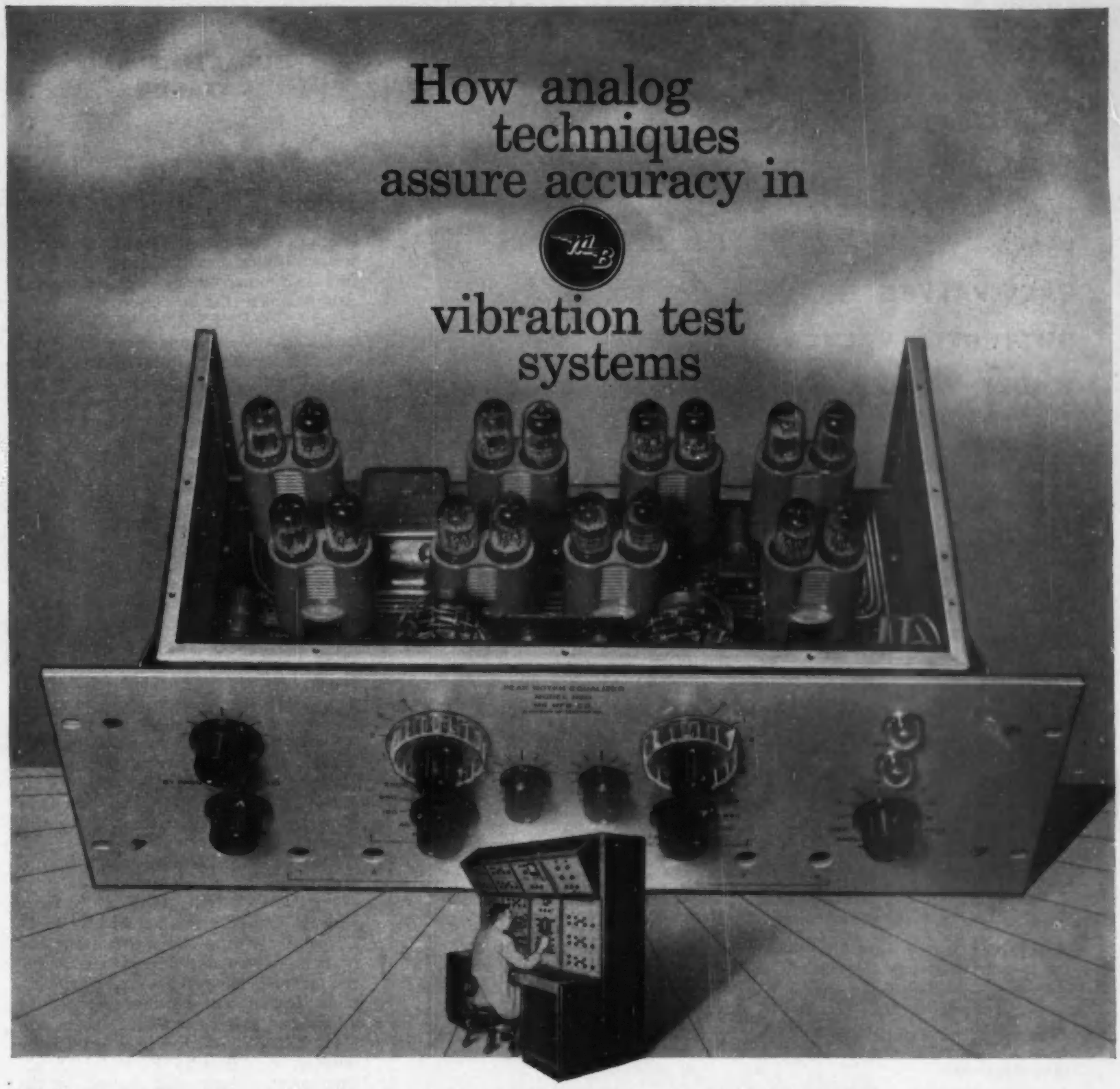
A comprehensive line of cables, designed for data transmission application and marketed under the trade name Datacable, includes the following types: low-capacitance, miniaturized coaxial cables, low-loss coaxial cables, and shielded, low-capacitance twisted pairs. A wide selection of electrical and physical characteristics is available.—Times Wire and Cable Co., Inc., Wallingford, Conn.

Circle No. 320 on reply card

RECTILINEAR POTS

A brand new series of ¾-in. diam cylindrical rectilinear pots offers virtually infinite resolution and an independent linearity within 0.2 percent. Models are available with single or dual elements, and strokes ranging from 2½ to 10 in. All display unique shock, acceleration, and vibration resistance in excess of 50g.—Markite Products Corp., N. Y., N. Y.

Circle No. 321 on reply card



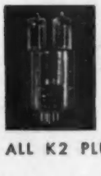
MB Electronics, manufacturer of complete complex motion testing systems, uses modern analog computor techniques to reproduce actual vibrational environments met in the operation of aircraft and missiles.

The MB Model T88 Complex Motion Console, which puts all the system controls within easy reach of a single operator, utilizes 10 Peak & Notch Equalizers — each containing 8 K2-W analog DC amplifiers by Philbrick. The equalizers are the key to test system accuracy. They adjust to the exact inverse electrical equivalence of the mechanical system resonance, and automatically provide the mass offset required for any table loading condition by assuring a flat frequency response identical to that of the input voltage.

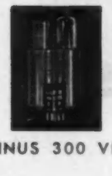
GEORGE A. **PHILBRICK** RESEARCHES, INC.
285 COLUMBUS AVE., BOSTON 16, MASS. TEL. COMMONWEALTH 6-5375

This is a special application, true. But it may provide the spark of an idea as to how you can use analog techniques — and efficient Philbrick plug-ins — to your advantage. Write for freely given opinions on your particular problem.

The analog way is the model way



MODEL K2-W — an efficient foolproof high gain operational unit for all feedback computations, fast and slow. A number of special varieties are also in quantity production. **$24.00**



MODEL K2-P — offers long-term, sub millivolt stability, by itself or with the K2-W. High impedance chopper-modulated input. Filtered output to drive balancing grid or follower. **$60.00**

MODEL K2-WJ — If the rigors of your application deserve a JAN-ized form of K2-W, the K2-WJ is now available. 5751 tubes and MIL standard components are used throughout at no increase in size. **$58.00**

ALL K2 PLUG-INS RUN ON PLUS AND MINUS 300 VDC AND 6.3 VAC. SOCKET WIRING IS SIMPLE AND STANDARDIZED.

CIRCLE 175 ON READER SERVICE CARD

BULLETINS AND CATALOGS

(355) NEW PNPN COMPONENT. Solid State Products, Inc. Bulletin C 410-01, 4 pp. Provides test specifications and ten design data curves on the Silicon Trigistor, a triggered bistable transistor. Recommended operation conditions, absolute maximum ratings, and mechanical data complete the coverage.

(356) CLUTCHES AND BRAKES. Dynamic Instrument Corp. Brochure, 4 pp. Tabulates operating characteristics of various magnetic clutches, magnetic and spring brakes, and clutch-brake combinations. Separate page covers environmental, electrical, and mechanical specifications.

(357) CARRIER MODULATION ANALYZER. Boonshaft and Fuchs, Inc. Technical Bulletin No. 91411, 4 pp. Contains data on the operation and circuit theory of a new test instrument, the Visual Phase Sensitive Detector. Drawings illustrate a typical test setup, a block diagram of the instrument, and the time relationship of various input and output signals.

(358) TINY TOGGLE SWITCHES. Haydon Switch Co. Bulletin No. 53T-1, 4 pp. Lists over 300 variations in a new line of subminiature toggle switches. Includes detailed descriptions of terminal configurations, contact arrangements, and electrical ratings.

(359) TRANSISTOR MOUNTS. Bendix Aviation Corp. Data sheet. Describes four new transistor mounting kits. Exploded views illustrate assembly and pertinent mounting dimensions.

(360) P-C CONNECTORS. U. S. Components, Inc. Catalog No. SF156UPCC. Describes electrical and mechanical specifications of two-unit printed circuit connectors and summarizes typical applications. Dimensional drawings and ordering information round out the coverage.

(361) PROCESS CONTROLS. B-I-F Industries, Inc. Bulletin B-I-F 5-1, 8 pp. Equipment, systems, and controls for the process industries are illustrated here as representative products of three separate divisions of the company. Application notes and a short summary of features and specifications accompany each illustration.

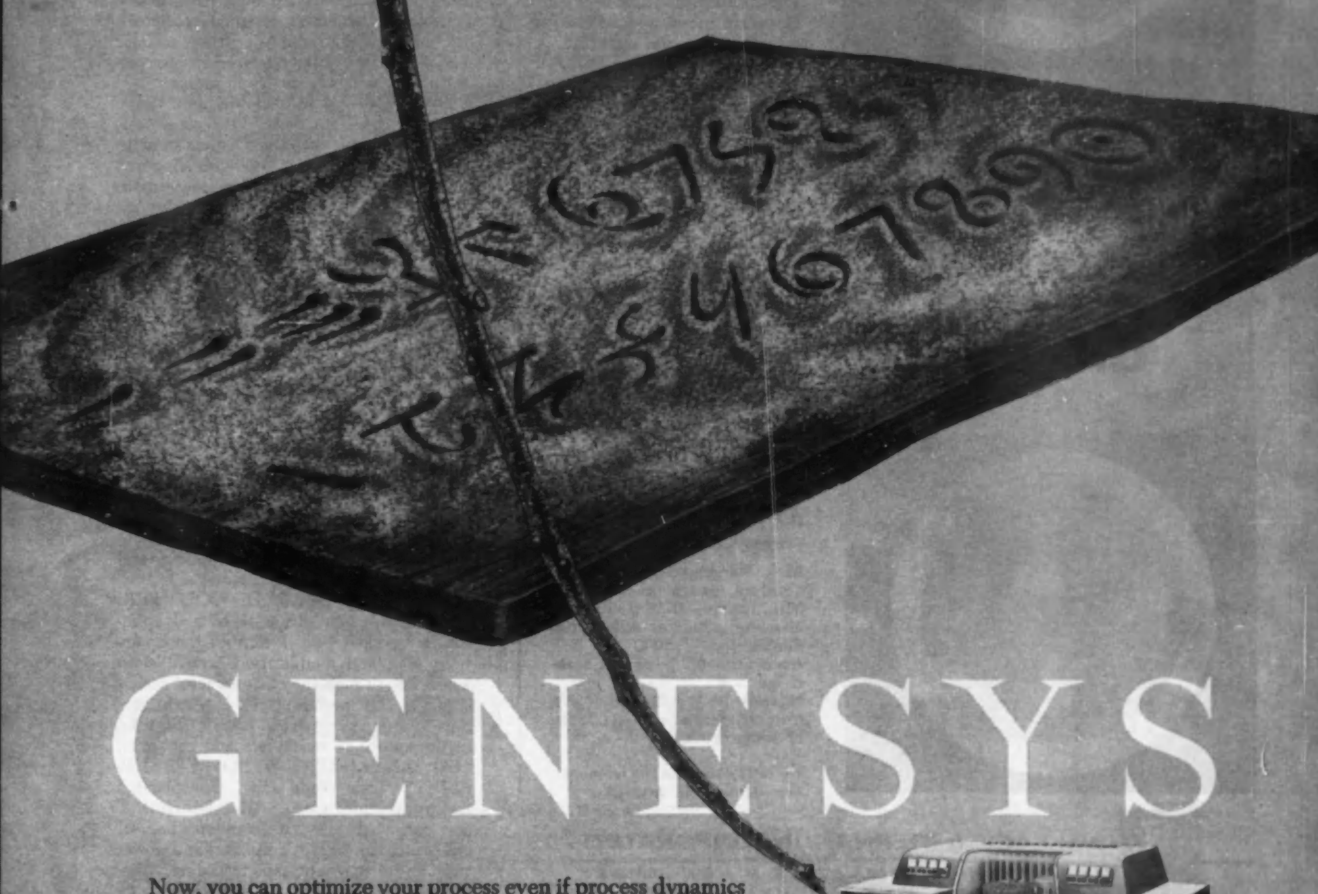
(362) VOLTAGE CALIBRATOR. Sensitive Research Instrument Corp. Data sheet, 2 pp. Announces a new rf voltage calibrator for standardization and calibration applications. Circuit diagrams illustrate two chief applications; text describes operation in both cases.

(363) IR EMISSION DETECTOR. Spectracoat, Inc. "Scanner", Vol. I, No. 3, 4 pp. Interesting technical discussion of an infrared system for velocity measurement, entitled, "Speedometer for an Astrogator". Other features include curves for the design of band pass filters and a description of a promising technique for the manufacture of ablation gages.

(364) DIGITAL VALVES & ACTUATORS. Ferguson, Hille & Associates, Inc. Technical bulletin, 3 pp. Covers a

FILLING THE VOID

in practical process control



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Now, you can optimize your process even if process dynamics are unknown! Custom designed for process control, the Genesys Digital Computer Control System is commercially practical . . . uses your existing instrumentation to control, analyze and optimize . . . delivers unmatched reliability with operational simplicity. Genesys Systems assure 4,000 hours (six months) of continuous onstream operation between scheduled maintenance periods. And your present operators get maximum performance from a Genesys with a minimum of training. Evaluate Genesys before you invest in process or pipeline automation programs. Compare the many exclusive advantages and unprecedented economies offered by the Genesys Digital Computer Control System. Write today for "Evolution in Process Control."

Seven giant steps forward in practical digital control, the UMP (Unit Memory Processor) was designed specifically for process and pipeline control, uses the best combination of digital equipment with practical speed matched to the problem.

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Bulletins & Catalogs

variety of valves, regulators, and positioners that can be used in digital control systems without requiring any conversion equipment.

(365) HIGH-GAIN AMPLIFIERS. George A. Philbrick Researches, Inc. Preliminary Data Sheet, 2 pp. Contains a general description of two high performance operational amplifiers designed specifically for military applications. Other sections review output capabilities, dynamic performance, and specific applications.

(366) WATER PROBLEMS. Betz Labs, Inc. Bulletin 596, 4 pp. Corrosion, scale formation, and slime and algae growths are some of the water problems discussed here. Bulletin offers concrete suggestions for the control of these problems through adequate, planned chemical treatment. Also includes application information as well as control testing data.

(367) DIGITAL SYSTEMS DESIGN. Computer Control Co., Inc. Booklet, 36 pp. "Symbolic Logic, Boolean Algebra, and the Design of Digital Systems" is the title of this booklet. Presents, in a clear and understandable form, the fundamentals of symbolic logic as applied to the logical design of digital systems.

(368) FIELD SERVICES. Labs Div. of Hoffman Electronics Corp. Brochure, 8 pp. Outlines the field services Hoffman offers on a world-wide basis in the areas of field engineering, overhaul and repair, test equipment, standards, training and medical electronics.

(369) NEW GEARED COUNTER. Veeder-Root Inc. Data sheet and application guide, 4 pp. Describes the operation, uses, and modifications available on a new line of high speed, quick reset geared counters. Of special interest is the description of a predetermining feature for automatic control of machinery and processes.

(370) AMPLIFIERS & POWER SUPPLIES. Data Tape Div., Consolidated Electrodynamics Corp. Five bulletins, 2 pp. each. Present a complete line of miniature, lightweight amplifiers and power supplies for magnetic tape recording. Photos and drawing illustrate operation, specifications, and applications.

(371) SERVOVALVE DATA. Moog Servocontrols, Inc. Catalog 310, 8 pp. Features a schematic diagram, detail cutaway photograph, and a series of definitive performance curves on Moog's new Mechanical Feedback Servovalve. Also contains a glossary of servovalve terminology.

(372) SERVO TECHNIQUES. Servo Corp. of America. Servo Design Report, SDR-1, 6 pp. Tells how to design, breadboard, and analyze servosystems rapidly, without need for fabrication of expensive intermediate prototypes. Photos illustrate how the packaged Servolab assembly of electronic and electro-mechanical components is being used by both industrial firms and engineering schools.

(373) POWER SUPPLIES. Sorensen & Co., Product Data Sheet, 4 pp. Sixty-three high voltage dc power supply models are described along with tabular specifications. Last page covers a variety of protective fea-

CIRCLE 179 ON READER SERVICE CARD

Bulletins & Catalogs

tures and optional equipment.

(374) FULL-OPENING VALVES. Rockwell Mfg. Co. Bulletin V-607 Rev. 1, 10 pp. Fully describes the Hypresphere line of full opening, lubricated spherical plug valves. Includes detail drawings, specifications, and dimensions for each size in the line. Both manual and power operation are discussed.

(375) INFRARED TECHNICAL DATA. Infrared Industries, Inc. Series of data sheets, attractively bound, represents an effort to provide complete information about infrared photoconductors and instrumentation. Material is aimed at design, test, and production engineers and others seeking a better understanding or contemplating use of infrared techniques.

(376) ELECTRONIC EQUIPMENT. Wayne Kerr Corp. Short-Form Catalog, 6 pp. Illustrates and describes some 20 products including instruments for the direct measurement of transistor characteristics under working conditions and balanced impedance. Product data and basic specifications are accompanied by photos in each case.

(377) TAPE INSTRUMENTATION. Minneapolis-Honeywell Regulator Co. Catalog DC-3171, 24 pp. Offers complete information on Honeywell's multichannel magnetic tape system for laboratories, test cells, telemetering recording, and other precision applications. Extensive performance specifications cover transports, FM, PDM, Direct and Digital tracks.

(378) IMPEDANCE MATCHING AMPLIFIER. Columbia Research Labs. Data sheet, 2 pp. Contains a detailed description of the operation of the Model 6000 impedance matching amplifier, a unit designed for handling high impedance signals. A set of significant performance curves completes the coverage.

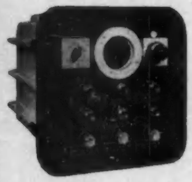
(379) TEST SYSTEMS. California Technical Industries. Catalog, 12 pp. Covers automatic testing, microwave and antenna test instrumentation, radome testing systems, and flight simulation equipment while describing the company's entire product line. Includes a 2-page price list.

(380) TIME DELAY RELAYS. Tempo Instrument Inc. Engineering Bulletin 5903, 3 pp. "Circuit Description", and "Design & Fabrication" are the lead-off sections in this bulletin. These are followed by a complete selection guide, specification notes, and special variations available for a complete line of precision time delay relays. Full page of application notes discusses recycling characteristics and the presence of noise and its effect on timing.

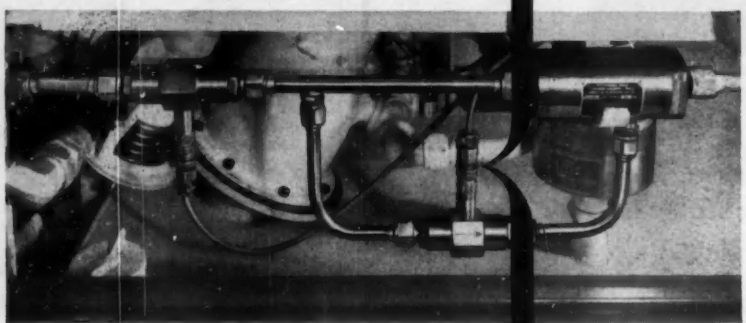
(381) SHAFT POSITION ENCODERS. Datex Corp. Bulletin No. 300-5, 4 pp. Summarizes standard and special features found in a complete line of shaft position encoders. Models cover both linear and non-linear calibration, internally and externally geared assemblies.

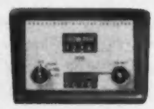
(382) SIGNAL GENERATOR. New London Instrument Co., Inc. Data Sheet, 2 pp. Lists specifications and design features of the Model 162 signal generator, a compact instrument suitable for design,

RACK MOUNTED INDICATOR

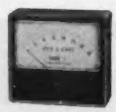


EXPLOSION-PROOF INDICATOR





TRANSISTORIZED INDICATOR



DIAL INDICATOR

COUNTER

production, and maintenance applications.

(383) OXYGEN ANALYZER. The Hays Corp. Publication 59-B633, 4 pp. Reviews details on the application, operation, and construction of the Model 633 suppressed range Oxygen Analyzer. Photo and line drawing of the analyzing cell illustrate discussion of the operating principle.

(384) INDUSTRIAL RECTIFIERS. Perkin Engineering Corp. Technical paper, 6 pp. Provides a basic explanation of the uses and types of semiconductor industrial rectifiers and covers such topics as monitoring, failure indication, current and voltage balance, overload protection, voltage surges, cooling, efficiency, and power factor.

(385) MODULAR ENCLOSURES. Elgin Metalformers Corp. Condensed Catalog 106, 16 pp. Covers basic frames and components used in the company's modular enclosure systems. Actually a condensed version of a comprehensive 108-page catalog.

(386) TECHNICAL NEWSLETTER. Helipot Div., Beckman Instruments, Inc. "Helinews" No. 20, 8 pp. Contains a number of product pointers, technical news stories, and a pictorial tour of the company's quality control facilities.

(387) "TURBO-METER". Rockwell Mfg. Co. Bulletin OG-417, 12 pp. Completely describes the functions, applications, and operation of the Rockwell Turbo-Meter, a practical high capacity meter designed for use in petroleum pipelines handling both crude and refined products. Also contains cutaway drawings, accuracy and head loss curves, and a list of important specifications..

(388) MAGNETIC STARTERS. Furnas Electric Co. Catalog 14-B1, 16 pp. Introduces a new, completely redesigned line of magnetic starters through 15 hp, 440-550 volts. Lists special design features and various optional field modifications.

(389) TARGET SIMULATOR. System Development Corp. Technical Paper, 12 pp. This was prepared for presentation at the Third National Convention on Military Electronics, sponsored by the IRE's PGME. In it, L. Michels and G. A. Hirschfield describe the design and operation of a controllable radar target simulator, developed for use in the manual system training program of the Air Defense Command.

(390) TINY TEMPERATURE CONTROLS. Fenwal, Inc. Bulletin MC-182, 4 pp. Offers complete descriptions of 19 different midget and miniature Thermoswitch controls. Dimensions, temperature range, electrical ratings, and available modifications are given for each unit. Also introduces the Model 32411, a brand new hermetically-sealed miniature control.

(391) GAS DRIVE AND TIMER. Rockwell Mfg. Co. Bulletin No. 1107, 4 pp. Photos and schematic drawings supplement this description of a self-contained air- or gas-driven instrument drive and timing unit for remote installations, such as off-shore oil wells and gas gathering systems.

WHAT'S NEW

(Continued from page 54)

tool builder plans to set up a foreign branch (bearing out the results of a survey conducted by the McGraw-Hill Dept. of Economics, CtE, Sept. '59, p. 46).

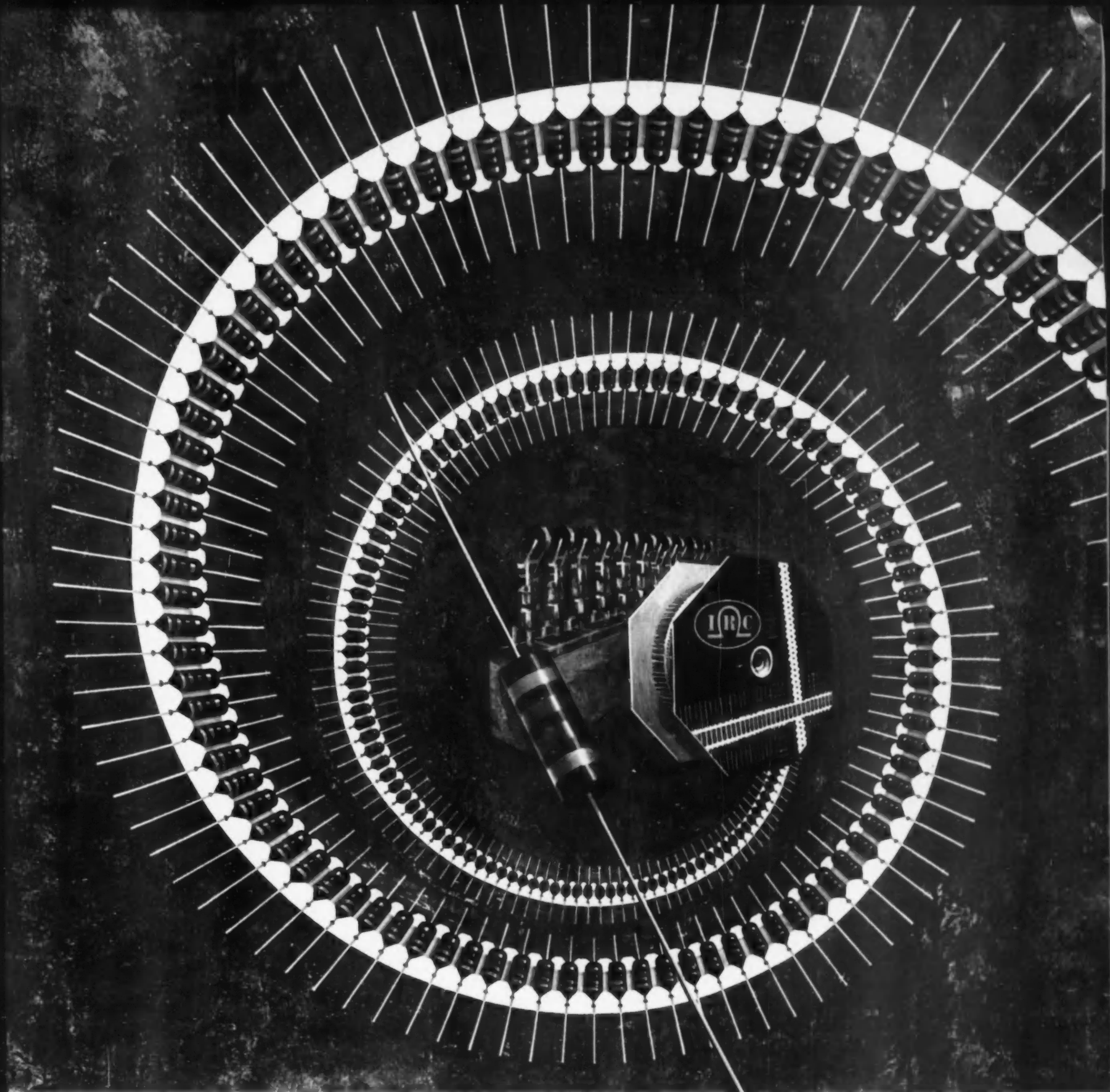
• **Thermostats for Brazil, Italy**—Robertshaw-Fulton Controls Co., Richmond, Va., revealed it will build two new plants overseas. The company is setting up Robertshaw-Fulton Controls Do Brazil S/A Industria E Comercio, which it will own in association with several Brazilian firms. The plant, to be built near Sao Paulo, Brazil, will make the company's line of automatic thermostatic controls available to the growing Brazilian appliance business.

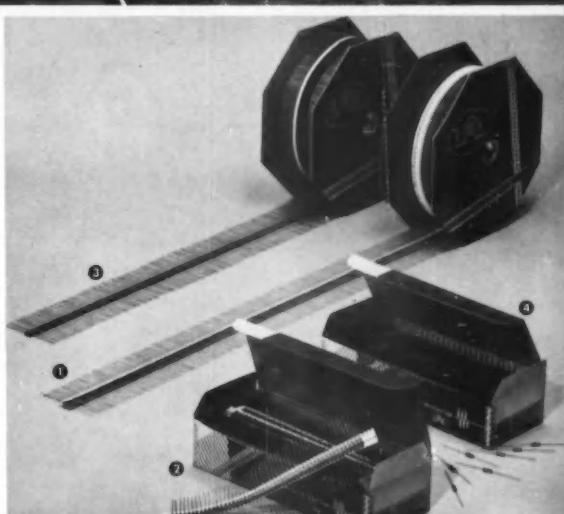
Robertshaw-Italia S.p.A. will be established near Turin, Italy, on the main route between Italy and France. The company will be owned jointly by Robertshaw-Fulton and Societa Italiana per il Gas, which supplies gas fuel to most of Italy. The plant will provide automatic thermostatic control devices for the growing European Common Market. Robertshaw-Fulton already has manufacturing and marketing units in Canada and Australia, an affiliate in West Germany.

• **A division for planning**—Another U. S. firm preparing to cash in on the opportunities afforded by the European Common Market is General Controls Co., Los Angeles producer of aircraft, industrial, appliance, and other controls. Six months ago General established a West German subsidiary, General Controls GmbH, in Dusseldorf, to start production of the company's air data computer for the West German version of the F-104. Now, an International Div. has been formed which will acquire other factories, open additional branch offices, and license new distributors overseas. First acquisition: Wirepots Ltd., a British manufacturer of precision potentiometers and dials. General's production of its line of pots will be shifted to the new plant, to be known as General Controls Ltd.

Laboratory for Electronics has also announced plans to set up an International Division. Its foreign arm will have headquarters in Geneva and Paris and will establish associated electronic companies in Europe to manufacture LFE products.

• **Tariff savings in ECM**—Hagan Chemicals & Controls, Pittsburgh, Pa., has started a foreign expansion program with the formation of two new operating companies in England and Switzerland. The company's purpose





electronic engineers:

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Hughes-Fullerton is recognized as an engineering-oriented organization, where the needs of the creative engineer are given precedence.

Privacy—At Hughes-Fullerton, engineers enjoy private or semi-private offices in new air conditioned quarters.

Creative Atmosphere—Engineers are encouraged to do independent thinking. The many Hughes-Fullerton "breakthroughs" are testimony of this unhampered atmosphere.

Research and Development Orientation—Because the bulk of Hughes-Fullerton projects start from "scratch," engineers have the satisfaction of being in on advancements in the state-of-the-art. At the same time, they can see that the final product fulfills program needs.

Long Range Projects—Hughes was first to develop three dimensional radar. Today this work is encompassing highly advanced data processing systems and electronic display systems.

Growth of Opportunity—Hughes-Fullerton (30 minutes from downtown Los Angeles), has grown from 800 employees in 1957 to 5,000 today. This programmed growth means unusual advancement opportunity. Engineers average age: 31. One out of five has an advanced degree.

It will pay you to investigate Hughes-Fullerton as the place to further develop your career as an engineer—no matter what your experience level.

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is to take advantage of tax and tariff benefits and compete more effectively in the Common Market.

Hagan Controls Ltd. will be based in London, and Hagan Pneutronics S.A. will be the Geneva subsidiary. Hagan already has a subsidiary in Canada, and its Italian sales licensee, the Termokimik Corp., will now also manufacture and service equipment in Italy for the Swiss firm.

Also of interest to control makers is Giddings & Lewis Machine Tool Company's announcement of an agreement with Douglas Fraser & Sons Ltd. of Abroath, Scotland, to form a British company, Giddings & Lewis-Fraser Ltd. The Fond du Lac, Wis., firm will own the controlling interest. The new company, using the manufacturing facilities of Fraser, will continue to make and market Fraser machine tools and will also produce G & L designs.

Servo Corp. Accuses GE, Wants $2¼ Million

Servo Corp. of America has filed a $2¼ million suit against the General Electric Co., charging patent infringement, unfair competition, and violation of the antitrust laws. Servo Corp., a Long Island, N. Y., electronic equipment maker, claims that GE willfully copied the former's patented Servosafe Hot Box Detective. The system uses an infrared device to spot overheated railroad car journal boxes ("hot boxes") and is installed and operating on 21 U.S. railroads (see CtE, May '57, p. 121).

Servo claims that its patent (No. 2,880,309) covers the Servosafe and that since the issuance of the patent last March, GE has been making and selling devices embodying the patented invention in its Waynesboro, Va., facility. GE has also, Servo asserts, copied from its maintenance manuals and other publications and published performance data originated by Servo. The company further contends that GE has been selling the allegedly pirated systems at a price that Servo believes must be a loss to GE and that the price cutting has caused cancellation of Servo orders.

Servo wants GE enjoined from making and selling the devices, pending the outcome of the suit in the Harrisonburg (Va.) District Court, and also permanently prohibited from doing so. Servo, which last year had sales of just over $4 million, also claims that it has suffered $750,000 in damages and

wants GE to pay them triple that because of the alleged willful nature of GE's actions. (Servo claims to have given GE written notice of its alleged infringements and infractions, with no results.)

Controls Set the Pace For British Industry

LONDON—

Sales of instruments and controls are leading an industrial recovery in Great Britain. Control products' sales are up five percent in the first five months of 1959, while industrial production increased, in the same period, for the first time in three years.

British economists had been concerned over the static condition of industrial production in England. It failed to increase from 1956 through 1958. And total manufacturing rose only one percent. Interestingly enough, instrument and control production failed to show such a plateau. Delivery of control products increased a tidy nine percent between 1956 and 1958. Even more outstanding was the rapid growth of United Kingdom computer makers; they boosted sales 40 percent in one year—1957-58.

July production figures show over-all industrial production up about one percent over the monthly average for the second quarter and more than three percent over the first quarter monthly average.

Exports of control products are increasing even faster than total sales. In the first five months of 1959, British control exports were up seven percent over the same period in 1958.

The statistics are based on reports from the optical measuring, control, and other scientific and industrial instrument industries and from computer manufacturers.

Victoreen, Tenney Merger To Form $15-Million Co.

Victoreen Instrument Co., manufacturers of radiation monitoring and control equipment, electronic devices, and neon display signs, and Tenney Engineering, Inc., manufacturer of environmental test chambers, have voted to merge to form Victoreen-Tenney Corp. The merger will be based on 8/10 of a share of Victoreen for each of the approximately 500,000 shares of Tenney outstanding (approximately 1.4 million shares of Victoreen are in the hands of the public).

Tenney recently acquired a major-

ity interest in PAM Associates, Inc., newly organized specialists in acoustical testing and control. The firm has also concluded an agreement with Consolidated Electrodynamics Corp. to combine research and engineering talent and technical facilities to produce equipment for simulating extremely high altitudes.

Victoreen's products, in addition to radiation systems and monitoring instruments, include: infrared detection devices; indoor and outdoor display signs—from its Kolux Corp. subsidiary; multi-channel analyzers and spectrometers and radiological instrumentation—from its Tullamore Electronics Corp. subsidiary; and missile and aircraft electronic products—from its Jordan Electronics subsidiary.

Officers of the new company, which expects annual sales of $15-million, will be David H. Cogan, chairman and president of Victoreen, with same titles in the new company; Saul S. Schiffman, chairman of Tenney, as chairman of the executive committee; and Monroe Seligman, Tenney's president, as executive vice-president.

Hewlett-Packard Acquires Boonton, Third Co. In 1959

Hewlett-Packard Co., Palo Alto, Calif., manufacturer of electronic measuring instruments, has made its third acquisition of the year. Boonton Radio Corp., New Jersey maker of signal generators and similar instruments, will become a wholly owned H-P subsidiary under the terms of the agreement that calls for an exchange of stock. Boonton has an annual sales volume of $2.5 million; H-P has sales of about $40 million.

Earlier this year, the company acquired two H-P-associated companies: Palo Alto Engineering Co., a manufacturer of transformers, coils, filters, potentiometers, magnetic amplifiers, and other components, with sales of over $1.5 million and Dymec, Inc., another Palo Alto manufacturer, with a line of instrumentation systems, radar simulators, and digital devices and sales over $3 million annually.

Avien To Get Luther Through Stock Transfer

Avien, Inc. and Luther Manufacturing Co. have concluded negotiations that will result in the purchase of the latter by Avien in an exchange of stock transaction. Avien, Woodside, N. Y., maker of instrumentation systems for fluids, temperature, and air-

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Apply *ElectroniK* precision and dependability to your gas chromatography measurements with this highly accurate recorder. It's *designed specifically* for gas chromatography—includes *only* necessary parts and functions.

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With this recorder comes the valuable plus you get with all Honeywell instruments—prompt, expert service . . . service you can depend on, in emergencies or any time, to protect your instrumentation investment.

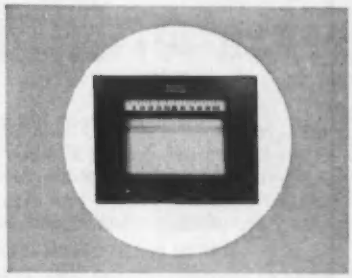

Chart speeds: ½, 1, 1½ and 2 inches per minute. Pen speed: 1 or 2 seconds full scale. Spans from 1 millivolt full scale.

For complete details on the gas chromatography recorder, call your nearby Honeywell field engineer. He's as near as your phone.

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craft and missile checkout equipment, expects the acquisition of the North Hollywood, Calif., electronic component company will provide it with a base for future growth in the west coast electronic, missile, and aircraft industries. It will also make available to Avien the services of a designer and builder of several electronic components presently used in its instrumentation systems. Luther's products include gyro and servomotors, synchros, resolvers, and subminiature relays.

Ampex Merges Orr Industries, Formerly Part-owned

Orr Industries, Inc. (formerly Orradio Industries, Inc.), manufacturer of magnetic tape, will merge with Ampex Corp., Redwood City, Calif., magnetic recording equipment company. Ampex has owned 25 percent of Orr for the past two years and has taken a part in the management of the company's plant in Opelika, Ala., during the past year. The agreement establishing the merger calls for one share of Ampex common stock to be exchanged for each 2.2 shares of Orr.

Electro-Mechanical Buys ASCOP For $3.8 Million

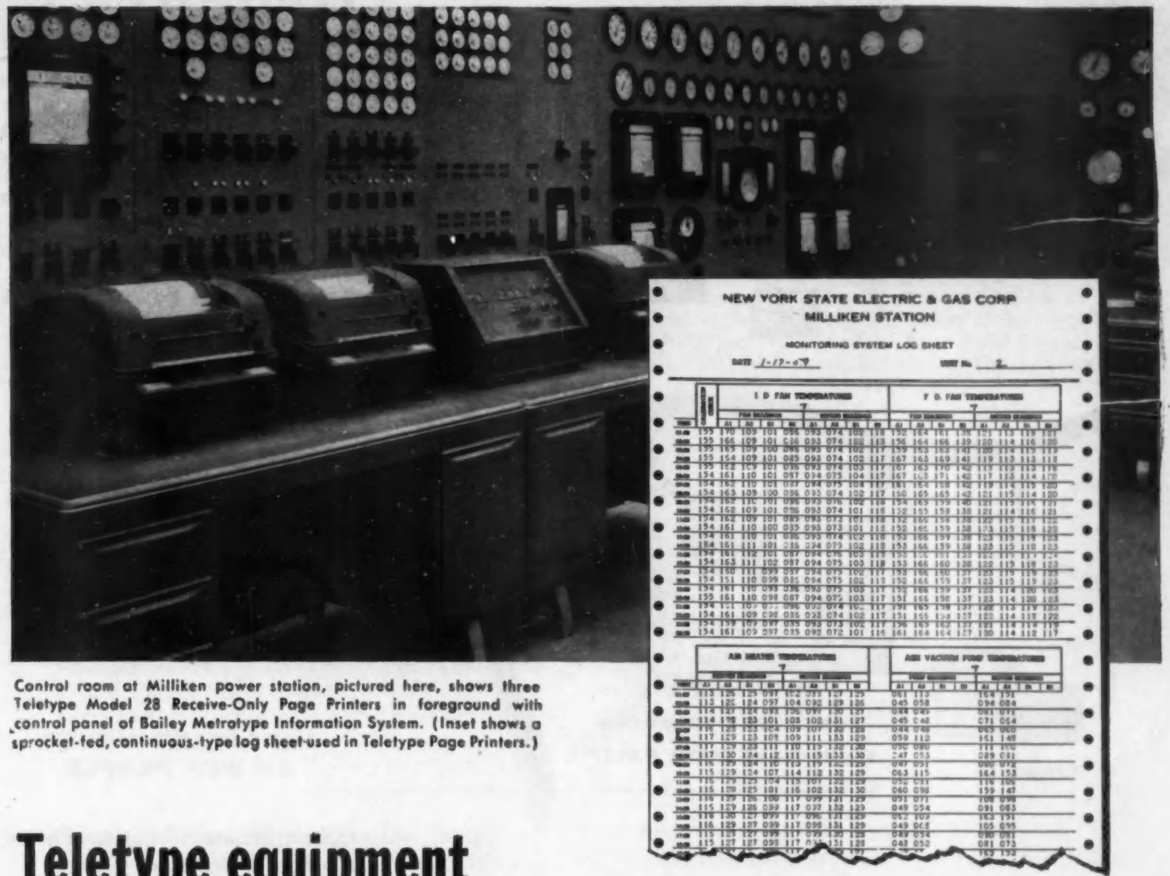
Electro-Mechanical Research, Inc., of Sarasota, Fla., has contracted to purchase the Applied Science Corp. of Princeton (N.J.) for approximately $3.8 million or about $9 per ASCOP share. ASCOP will be managed as a division of EMR, which, in turn, is a wholly owned subsidiary of Schlumberger, Ltd.

Argonne National Lab. Sets Up Solid State Div.

To further its studies of the nature of matter, Argonne National Laboratory, operated by the University of Chicago for the U. S. Atomic Energy Commission, has set up two new divisions, High Energy Physics and Solid State Science. The energy group, headed by Dr. Roger Hildebrand, will investigate the elementary particles from which matter is made, using the Lab's. 12.5 billion electron volt particle accelerator, now being built.

The solid state unit will be directed by Dr. Oliver C. Simpson and will undertake studies to obtain materials that will withstand conditions thought impossible a few years ago. In some of their studies, Argonne scientists will use beams of "cold" neutrons from the Lab's. nuclear reactor as probes

Automatic read-out . . .



Control room at Milliken power station, pictured here, shows three Teletype Model 28 Receive-Only Page Printers in foreground with control panel of Bailey Metrotype Information System. (Inset shows a sprocket-fed, continuous-type log sheet used in Teletype Page Printers.)

Teletype equipment monitors and records power station performance

New Model 28 Teletype Page Printers and Tape Punch equipment provide a continuous, dependable data processing facility for evaluating power station performance. This Teletype communication equipment is part of a Bailey Meter Company Metrotype® Information System installed recently at the Milliken power station of the New York State Electric & Gas Corporation, near Ithaca, New York.

This installation consists of two data systems:

1. A Monitoring System that continuously scans a total of 282 variables—temperatures of fan, motor and pump bearings; pressures of water and oil pumps, etc. Whenever readings exceed prescribed limits, system immediately reads and prints complete digital data of off-normal operation. In addition, complete readings are printed hourly.

2. A Performance System that scans 66 points once every hour, measures generator output, main steam flow, feedwater flow, temperatures, etc. All factors required to evaluate the station's performance are logged on the Teletype Printers. A Teletype Tape Punch also produces a perforated tape for IDP.

Robert Darke, Systems Division Manager, Bailey Meter, says, "Teletype equipment was chosen for this installation because of its flexibility and proven reliability. Design is simple and trouble-free, and the units are manufactured specifically for round-the-clock rather than intermittent service."

Teletype equipment will handle data for virtually any purpose in any industry. Signals may be serial or multi-wire. Signal medium may be local electrical circuit, telegraph or telephone circuit, or radio.

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for the determination of the frequency spectrum of solids. In addition to "cold" neutrons, scientists in the new division will perform experiments with other forms of radiation—X-rays, electrons, visible and ultraviolet light, and microwaves. Substances will also be studied at temperatures approaching absolute zero.

Kearfott Adds Power Supplies To Components Line

Kearfott Co., Inc., Clifton, N. J., producer of gyros, inertial guidance systems, and other precision components, has formed a new Power Equipment Div. to design and manufacture rotating and static power supplies and associated control equipment. Frank G. Logan, formerly with Vickers, Inc. and with Kearfott since May 1, will be general manager of the new division. The power supplies will be marketed to customers in both the military and commercial fields.

IMPORTANT MOVES BY KEY PEOPLE

Orbom Named As Epsco Enters Medical Electronics Field

Through its Epsco-Worcester (Mass.) division, Epsco, Inc. has entered the field of electronic medical diagnosis and has named Orville E. Orbom as the division's head. Prior to joining Epsco in 1958, Orbom was a research engineer with Alcoa and engineer in charge of automation at Allegheny Ludlum Steel Corp.

The new division also manufactures graphic recording equipment for industrial applications. Instruments in the medical diagnosis line in production include electrocardiographs and electro-encephalographs.

Honeywell Names Three In Research Moves

Minneapolis-Honeywell Regulator Co. has made three personnel shifts in its research set-up: Dr. Finn J. Larsen has been named to the new post of vice president in charge of research; William F. Newbold is the new director of research for the Brown Instruments Div.; and Walter P. Wills has moved up to technical director of engineering, a new post at Brown.

Dr. Larsen will continue to direct

Wiley BOOKS

1. HANDBOOK OF AUTOMATION, COMPUTATION, AND CONTROL, VOLUME 2: COMPUTERS AND DATA PROCESSING

Edited by EUGENE M. GRABBE, SIMON RAMO, *and* DEAN E. WOOLDRIDGE, *both of Thompson Ramo Wooldridge Inc.*

One of three volumes that form a complete control systems handbook. They cover in great detail research, development, design, and application. The system engineering concept is stressed throughout.
Volume II brings together available techniques for *design* and *use* of digital and analog computers. Included in the computer sections is practical material on design of computing elements and on equipment operation. The sections on components stress recent developments such as magnetic cores and transistors. An entire section covers programming and coding. ***1959, 1093 pages. $17.50 Vol. I: Control Fundamentals. 1958. 1020 pages. $17.00. Vol. III: Systems and Components. 1960. In Press.***

2. SERVOMECHANISMS AND REGULATING SYSTEM DESIGN, VOL. 1

SECOND EDITION

By HAROLD CHESTNUT *and* ROBERT W. MAYER, *both of General Electric Co.*

A complete revision of a classic, expanded by about 15%. The book starts with basic mathematics, describes the nature of the physical problems involved, then proceeds to solutions of advanced designs. Major additions are a chapter on applying root-locus to feedback problems, and a chapter on analog computers as design tools. Four new features: 1) updates nomenclature and definitions, in accordance with modern practice; 2) modifies material on transfer functions, to stress the loading effect of one element on another; 3) adds new ways of relating open-loop frequency response to approximate closed-loop transient response; 4) recasts completely the chapters on error-coefficients and transfer function.

1959. 680 pages. $11.75

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3. NONLINEAR PROBLEMS IN RANDOM THEORY

By NORBERT WIENER, *M.I.T.* The role of biological nonlinear processes in studying self-organizing systems, and nonlinear coding processes in communication theory. A Technology Press Research Monograph M.I.T.

1958. 131 pages. $4.50

4. ELECTROMECHANICAL ENERGY CONVERSION

By DAVID C. WHITE *and* HERBERT M. WOODSON, *both of M.I.T.* Gives fundamentals of electromechanics, then uses them with selected models to derive dynamics of typical physical devices. *1959. 646 pages. $12.50*

5. SAMPLED-DATA CONTROL SYSTEMS

By ELIAHU I. JURY, *Univ. of California.* Basic methods of analysis and synthesis in sampled-data systems and related fields, applied to circuits, networks, computers, and the general field of system engineering. *1958. 453 pages. $16.00*

6. JUNCTION TRANSISTOR ELECTRONICS

By RICHARD B. HURLEY, *Univ. of California.* Presents a *realistic* treatment of basic knowledge for the understanding of characteristics and applications of transistors.

1958. 473 pages. $12.50

7. DYNAMICS OF FLIGHT

Stability and Control, *by* BERNARD ETKIN, *Univ. of Toronto.* For airplanes of all types, including missiles. Covers static, dynamic stability; transient, frequency response; feedback, automatic controls; machine computation.

1959. 519 pages. $15.00

8. FUNDAMENTALS OF ADVANCED MISSILES

By RICHARD B. DOW, *U. S. Air Force.* Covers principles of propulsion, aerodynamics, guidance, control of missiles and space vehicles. Applications in terms of theory, experiment, and practice. *1958. 567 pages. $11.75*

9. SPACE TECHNOLOGY

Editor, HOWARD S. SEIFERT, *Space Technology Laboratories, Inc.* 38 contributors. The first collection of serious analyses. A thorough quantitative treatment of laws uniquely related to space flight, by acknowledged leaders in the field.

1959. 1188 pages. $22.50

10. ECONOMIC CONTROL OF INTERCONNECTED SYSTEMS

By LEON K. KIRCHMAYER, *General Electric Co.* Treats mathematical methods, controllers and computers and their uses in arriving at the most economic operation of utility systems. *1959. In Press.*

11. ELECTRONIC PROCESSES IN SOLIDS

Lectures by P. AIGRAIN. *Edited by* R. J. COELHO *and* G. ASCARELLI, *M.I.T.* A Technology Press Research Monograph, M.I.T. *In Press.*

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the activities of Honeywell's central research labs in Minneapolis, where he has been research director since 1953. He will also provide research program guidance for all company divisions. Newbold, who replaced Wills, has been with Brown since 1948, serving as research engineer, assistant to the director of research, section head, and assistant research director. Wills joined Brown in 1936 as a research engineer and was manager of research and development before becoming director of research in 1955.

Franklin Institute To Honor Potter

David M. Potter, the inventor of the Pottermeter, turbine-type flowmeter widely used in jet and rocket engine development and performance, has won the Franklin Institute's Edward Longstreth Medal.

The Institute, founded in Philadelphia in 1824 as a scientific and educational organization, has awarded the medal since 1890 on an international basis for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. Other Longstreth medalists include Thomas Edison and Elmer A. Sperry, Jr.

Potter, who is president of Potter Aeronautical Corp., Union, N. J., and Potter Pacific, Malibu, Calif., will be awarded the medal at ceremonies in Philadelphia, October 21.

Wilson Leaves Daystrom To Join General Mills

Richard A. Wilson, former Daystrom, Inc. vice-president, has become vice-president of General Mills, Inc. and general manager of the company's Mechanical Div. In addition to being Daystrom's vice-president, Wilson also served as president of several of the firm's divisions. Before joining Daystrom, Wilson was, for seven years, vice-president of the Magnavox Co. and general manager of its Government and Industrial Products Divs.

Successor To Varian Two Others Appointed

Dr. Edward L. Ginzton is the new chairman of the board of Varian Associates, to fill the vacancy left by the recent death of Dr. Russell H. Varian (CtE, Sept. '58, p. 301). Like his predecessor, Dr. Ginzton was one of the founders of the Palo Alto, Calif.,

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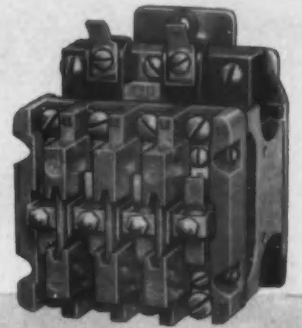

TYPE C—30, 40, 50 AMP. 2-3-4 pole 30 amp.—600 volts. 2-3-4 pole 40 amp.—230 volts. 2 pole 50 amp.—230 volts. Same mounting holes and coils for all ratings and pole forms.

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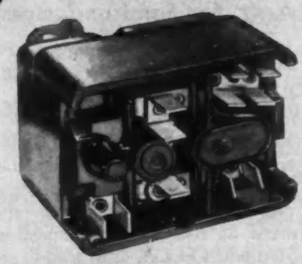
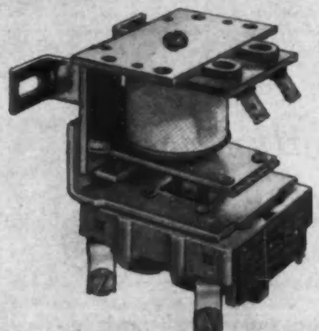
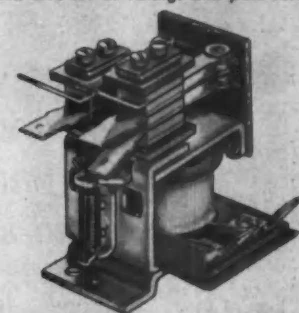


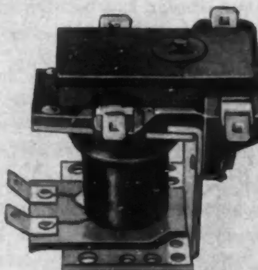
SERIES 128000 POTENTIAL STARTING RELAYS For starting single phase capacitor start compressors.



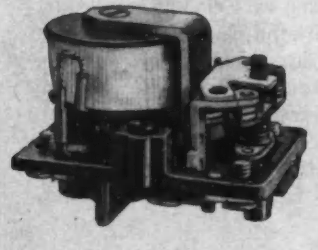
TYPE 80 CONTROLLER Specific design for nominal 3 HP or 3-ton single phase compressors.



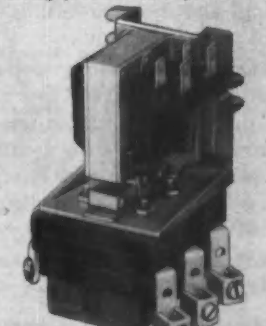
GENERAL PURPOSE RELAY 98000 Series AC or DC. Permits engineering short cuts lowering your "finished product" cost.



TYPE 75 Low cost power relay. Dependably handles up to 6000 W. at 240 V., resistive load per pole. Compressor rating 2 poles, 18 amp. running, 90 amp. locked rotor at 250 volts.



SERIES 129000 SHUNT TYPE RELAY—SPNO, SPNC or NO-NC For standard commercial voltages. Other coils available for special application. For heater, fan control, general circuit switching, etc.



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SX

RBM Controls Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at Peru, North Manchester and Logansport, Indiana

company and has served as a member of the board since the firm's inception in 1948. He is director of the microwave laboratory and professor of applied physics and electrical engineering at Stanford University. He has also headed the university's linear accelerator program.

Edward W. Herold was appointed vice president for research, a new post at Varian, after resigning as director of RCA Laboratories' Electronic Research Lab. Dr. Louis Malter will head a new Vacuum Products Div. at Varian. He joined the company in 1958 as director of central research, coming from a post as chief engineer of RCA's Semiconductor and Materials Div. The new Varian division will develop, produce, and sell VacIon trademarked pumps, vacuum components, and systems and vacuum electronic devices.

Rheem Names Manager, Ass't. for Semiconductors

Rheem Semiconductor Corp., Mountain View, Calif., subsidiary of Rheem Manufacturing Co., has named Dr. Henry Marcham to be manager of engineering (and also vice-president) of the semiconductor manufacturer. Before joining Rheem, he was director of chemicals development at the research department of Standard Oil Co. (Ind.) and, previous to that, assistant director of development for Velsicol Chemical Corp. Dr. Marcham has also had experience with Hercules Powder Co. and Sylvania Electric Co. He had been an assistant professor of engineering at Carnegie Institute of Technology.

Also just appointed is a new assistant manager of engineering, David F. Brower, who has done research in controlled thermonuclear research at the General Atomic Div. of General Dynamics Corp. Previously, he had engaged in computer components research at Hughes Aircraft Co. Brower also comes from Carnegie Tech.

Sisson Chief Engineer At Reorganized F. W. Bell

Edwin D. Sisson has been appointed chief engineer of F. W. Bell, Inc., Columbus, Ohio, instrumentation devices maker. He was recently with the Bell Sound Div. of Thompson Ramo Wooldridge, Inc. Sisson began with that company in 1943, when it was known as Bell Sound Systems, Inc. and was headed by F. W. Bell; the firm became a division of TRW

in 1953. F. W. Bell, Inc. was formerly American Electronic Corp. and was reorganized in June of this year.

Other Important Moves

Allan W. Greene is the new president of the Heath Co., Benton Harbor, Mich. The position had been filled by Daystrom president Thomas Roy Jones since Heath's former president Robert Erickson joined Beckman Instruments last year. The division of Daystrom, Inc. makes electronic equipment in kit form. Greene previously had been vice-president of Moto-Mower, Inc.

Dr. Paul F. Pegerey has been appointed research director of the Taylor Instrument Companies. Dr. Pegerey started his career as an apprentice toolmaker and became a tool and machine designer. He then decided to further his education and earned Bachelor's, Master's, and Doctor's degrees from Purdue. He joined Taylor in 1953.

James T. Bradford, Jr., has taken over the new position of electrical control engineer for Jones and Laughlin Steel Corp. He had been a control engineer for General Electric Co.

Dr. Miguel A. Xavier will be chief engineer of Century Electronics & Instruments, Inc. of Tulsa, Okla. He will guide the activities of the company's research and development. Dr. Xavier comes from Cook Electric Co.

Fred Rauschenbach, for two years sales manager of Martin-Baltimore, has joined United ElectroDynamics, Inc. of Pasadena, Calif., as manager of development planning.

James Hamilton has become manager of manufacturing engineering of the General Purpose Control Dept. of General Electric Co. in Bloomington, Ill. He joined GE in 1947 after positions in Scotland and with Rolls-Royce, Ltd.

Roy G. Knutson is the new manager of advanced engineering at Autonetics, a division of North American Aviation, Inc. He has been with NAA since 1946.

W. M. Wochos has been appointed general manager of Elgin Micronics-West Coast, a division of Elgin Watch Co. Wochos was promoted from the position of manager of the west coast plant in Chatsworth, Calif. He began

his career with Elgin in 1941, was appointed operations manager of the company's Industrial Products Div. in 1955, and was manager of Elgin's ordnance plant, the predecessor of the Micronics Div.

William E. Seaman has been named chief engineer of Midwestern Instruments, Inc., Tulsa, Okla. He will head the company's engineering department in developing and producing recording instrumentation, telemetering equipment, servomechanisms, and tape recorders. Seaman comes from the Ampex Corp., where he has been employed for the past six years.

Robert W. Deichert has been promoted to engineering manager for scientific instruments of the Industrial Electronics Div. at Allen B. Du Mont Laboratories, Inc. He will have overall engineering and design responsibilities for the company's oscilloscopes and related electronic test equipment and accessories. **Richard T. Petruzelli** will take over Deichert's former position as manager of the Data and Display Laboratory.

David A. Young, Aerojet-General's first employee when the company was founded in 1942, has now been appointed director of the corporate long range planning division of the Azusa, Calif., General Tire and Rubber Co. subsidiary. Young was recently chief of the space technology program for the government's Advanced Research Projects Agency.

George F. Kennard has been named manager of the research and engineering department, and **Dr. Thomas R. Horton** has assumed the new post of manager of the systems analysis department at the Federal Systems Div. of International Business Machines.

E. O. Vetter, an assistant vice-president at Texas Instruments, Inc., has moved up to vice-president and manager of TI's Metals & Controls Div. After joining TI in 1952, from Standard Oil of Calif., Vetter was vice president of the Geophysical Service, Inc. subsidiary and later was manager of the Industrial Instrumentation Div.

Obituary

Vincent R. (Pete) Murphy, Jr., 39, manager of special products for Reliance Electric & Engineering Co.; in Lakeside Hospital, Cleveland, Ohio.

Excerpts From NACA Report

From the "Forty-fourth Annual Report of the National Advisory Committee for Aeronautics — 1958" NACA Headquarters, Washington, D. C. (Final report.)

The following excerpt, taken verbatim from the committee's administrative report to Congress, covers some of the recent NACA activities in the fields of automatic control and instrumentation. Ed.

Aircraft and Spacecraft . . .

Flight control studies of current high-performance airplanes and advanced airplane-design concepts have included ways and means of providing, automatically, stability and control characteristics acceptable to the human pilot for specific tasks such as landing and target tracking and completely automatic flight-control where improved performance dictates.

Slow airplane response to various control commands such as roll, yaw, and throttle adversely affects the pilot's ability to control an airplane in landing approaches. Flight studies conducted in smooth and rough air with an airplane modified to provide artificial variation of roll and yaw damping have provided boundaries defining acceptable levels of damping and control response. Flight studies have also shown automatic throttle control to be a promising way of allowing reduced speeds in landing-approach maneuvers.

In many high-performance airplanes it is possible for the pilot to exceed inadvertently the design loads in accelerated and/or high angle-of-attack maneuvers. Analytical and ground simulator studies of an elevator-motion braking device actuated by normal acceleration, pitching acceleration, and pitching velocity signals were extended to flight. The flight studies indicate that inadvertent accelerations will be limited to tolerable levels.

Other studies have resulted in the development of a method of predicting the relative severity of pitchup and the effects of aerodynamic modifications and stability augmentation devices on several supersonic airplanes with pitchup problems. An automatic pitchup control system incorporating an angle-of-attack sensing device to retrim the horizontal stabilizer as the "pitchup region" is approached and entered has alleviated the pitchup considerably on a test airplane.

To increase the utilization of computer systems carried on aircraft, it has been thought that some functions need not be carried as continuous processes but could be handled intermittently on a time sharing basis. Studies of yaw and pitch stabilization have led to the belief that discontinuous control systems could reduce complexity and system power requirements of airplane automatic control systems. A study has been made of the application of sampled-data theory to an airplane with an altitude control system. A better understanding of switching criteria has been obtained and should lead to useful design techniques.

On future airplane designs it may be necessary to tolerate marginal levels of static and/or dynamic stability for reasons of performance improvement and to obtain desired characteristics by stability augmentation. The problem of marginal flight control characteristics when the primary stability augmentation system fails has been studied to determine whether the pilot can cope with the emergency or whether secondary systems must be provided.

An airplane which can have its longitudinal dynamic response and control system characteristics varied has been utilized in a study of control system dynamics. Similar studies have been made on a ground-based simulator. Insight has been gained regarding the desired dynamics of longitudinal control systems for airplanes varying from transport types to those proposed for atmospheric reentry.

Studies of airplane control systems where the pilot controls the airplane through commands to an automatic pilot were extended to take into consideration flight in rough air and flight at negative static stability margins as may be encountered at subsonic speeds by hypersonic designs. The systems involving angular-rate command and normal-acceleration command appear to be able to cope with small degrees of longitudinal instability.

The use of information derived from airborne radar equipment tracking a target at the end of a runway to assist in making an automatically controlled approach has been studied analytically. Such systems would eliminate the need for auxiliary ground equipment as employed in present landing control systems and make use of radar equipment already

carried on many airplanes for other purposes. A usable airplane control scheme has been devised.

Flight and analytical research has continued on tracking control problems of current and projected interceptor airplanes. Studies included consideration of computer and radar display parameters for manual-mode tracking and study of factors that affect flight path stability and aiming accuracy in attacks with an automatically controlled interceptor, including consideration of system changes to improve performance against maneuvering targets. Studies were also made of the effects of high closing rates with consideration of the effects of interceptor maneuverability on guidance systems designed for interception in collision course attacks, and of an automatically controlled interceptor using bank-angle-error for lateral-control commands.

Piloting problems in exit and entry of manned flight from the atmosphere of the earth expose the pilot to an acceleration environment beyond his past experience. A joint NACA-contractor-military service program in support of the X-15 airplane program was conducted in a centrifuge to determine the effects of typical exit and entry acceleration time histories on pilots' ability to control the airplane. Specific factors considered were airplane stability augmentation and flight data presentation to the pilot. Other studies with hypersonic airplane-type configurations have involved the use of a ground-based flight simulator to investigate damping requirements with regard to longitudinal, lateral-directional, and roll modes of motion.

Prediction of the dynamic behavior of large vehicles representative of ballistic missiles, hypersonic aircraft, or spacecraft during boost is complicated by the characteristic light-weight, flexible structure, and the large variable internal mass. In order to understand the stability and control problems of this class of vehicle, studies were undertaken considering autopilot and thrust control response, aerodynamic forces, fuel sloshing, and structural elasticity. These studies have given some insight to the problem of automatically stabilizing high-performance vehicle systems. . .

The flight dynamics of vehicles reentering the earth's atmosphere must be such that the vehicle does not exceed limiting attitude angles

associated with aerodynamic heating and/or other structural considerations. Studies have been conducted to determine the degree of inherent aerodynamic or artificial stability required for typical bodies. Studies have also been made of the possible utilization of a man aboard a satellite. . .

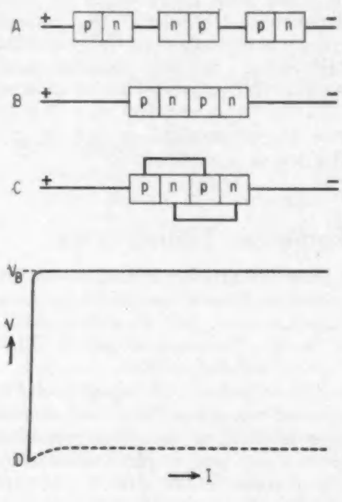
Preliminary considerations indicate that certain types of satellites will require accurate placement in orbit and accurate control of attitude. In a generalized investigation of satellite stabilization and control, consideration was given to such matters as the earth's force fields, internal power requirements and sources, control and sensing devices, and initial placement of the satellite in the design orbit. The matter of attitude control was given special consideration. Control systems considered include hydrogen peroxide jets, inertia wheels, and permanent magnets that react with the magnetic field of the earth.

P-n-p-n Switches

From "Two-Terminal p-n-p-n Switches", by J. M. Goldey, "Bell Laboratories Record", June 1959, pp. 223-226.

Switches may be classified generally as "non-regenerative" or "regenerative". When a stimulus changes the state of a non-regenerative switch, the new state persists only so long as the stimulus is present. In the case of a regenerative switch, the new state is maintained after the stimulus is removed.

The two-terminal p-n-p-n transistor is a regenerative switch. It is like



three single-junction p-n diodes in series, as in part A of the figure. For the polarity indicated, the junctions at the two ends are both forward bi-

ased, and therefore are of low impedance. The center device, however, is reverse biased and presents a high impedance to current flow when voltages lower than the breakdown voltage are applied. If the interior n and p regions are merged, as in B, a single device of p-n-p-n structure results. Now, as long as the interactions between the outer junctions and the inner junction remain small, the p-n-p-n structure acts like the three separated single-junction devices to maintain a high impedance characteristic. This characteristic is shown by the solid line in D. With large junction interaction, the p-n-p-n structure acts like three single-junction devices in parallel, or effectively a single forward-biased junction. This is illustrated schematically in C. The voltage-current characteristic in this case is the dotted line in D.

Designers have several methods by which they can vary the junction interaction. One of these makes use of certain imperfections in the crystal that may be produced either chemically or mechanically. These imperfections suppress junction interaction in a semiconductor when low currents flow but permit interaction at moderate and high current levels.

Typically, the breakdown voltage of a two-terminal p-n-p-n transistor used as a telephone talking path switch is 50 volts. Both the forward and reverse breakdown voltages are designable, however, and thus devices can be made with many values of these parameters. Similarly, the turn-on current is typically 1 ma but controlled high-energy electron bombardment permits this parameter to be adjusted between 50 μa and 100 ma. The device can be switched on and off in a fraction of a microsecond.

Radiation Bibliography

From "Radiation Detection—A Literature Search" compiled by J. A. McCormick. United States Atomic Energy Commission report TID-3518, February 1959.

This report is a bibliography of 335 selected references on detection and measurement of radiation from isotopes when used in physical and biological research. These references were selected from scientific journals published during the years 1948-1957. A list of journals from which the references were selected and an author index are included.

NEW BOOKS

Advanced Text

LINEAR NETWORK ANALYSIS, by *Sundram Seshu and Norman Balabian, Syracuse University.* 571 pp. *Published by John Wiley and Sons, New York.* $11.75.

This book is designed as a first year graduate-level text book on network theory, transients in linear systems, and feedback analysis. Active networks, passive networks, and many different ways of treating them are combined so that this book forms an excellent introduction to advanced circuit analysis. The authors write in a first person style; the text reads like a tape recording of a series of excellent lectures. This book was written particularly for the graduate electrical engineering student who will go on to take more courses in network analysis and who is more interested in basic concepts than design short-cuts. It is not recommended for home study unless the reader is already fairly well versed in the field because a great deal of the material covered assumes that the reader has a thorough knowledge of complex variables, Laplace operational calculus, and a familiarity with electrical networks. The topics covered include the following: writing equations, matrix algebra, topology, network analysis, network theorems, transfer functions, transfer function analysis and synthesis, feedback theory, and filter theory. The book is limited to linear systems with lumped parameters. Both analysis and synthesis are covered.

Ira Ritow
Airborne Instrument Lab.

Fundamental Text

TRANSISTORS. *Angelo C. Gillie, Ward School of Electronics.* 262 pp. *Published by Prentice-Hall, Inc., New York 11, N. Y.* $7.95.

Intended primarily as the basis for an introductory course for technicians, this book could also serve as a survey text for undergraduate students. The practicing engineer who wishes to be introduced to the transistor also will find that this book provides a more comprehensive generalized coverage of transistors than many of the other texts presently on the market. Transistor behavior is described without recourse to advanced mathematics. The presentation is such that any one familiar with Ohm's Law, basic electrical theory and fundamental algebra

NEW BOOKS

can assimilate the material with ease.

The first three chapters provide an easily understandable explanation and a discussion of amplifiers from the viewpoint of nonlinear resistive control devices. This presentation serves as background preliminary to embarking into the study of transistors. Chapter 4 presents the atomic and operational characteristics of the most commonly used semiconductor materials, germanium and silicon, and is followed with a nonmathematical explanation of diode action. Chapter 6 discusses the photo transistor and some of its applications. The major chapters 7 and 8 are concerned with the junction transistor theory and characteristics and some of its more common applications. Chapters 9 and 10 devote an understandably brief amount of space to the discussion of the point contact transistor and its applications. Sufficient detail is presented, however, to provide the reader with an awareness of point contact transistor characteristics. The text concludes with coverage of other semi-conductor devices.

An attractive feature of this book is the rather complete set of questions and problems. An unfortunate omission is a bibliography.

Albert N. De Sautels
Maico Electronics Inc.

One from Russia

DESIGN OF MAGNETIC AMPLIFIERS (*Russian*), by N. P. Vasilieva, O. A. Sedikh, and M. A. Boyarchenkov. 335 *pp. Published by* Gocenergoizdat, *Moscow.* $5.

This book covers practical magamp design methods rather than theoretical considerations. It explains how to design a magnetic amplifier based on the following requirements: maximum power delivered to the load, load impedance, power gain, and the ratio of maximum to minimum load current. After a particular circuit and core material have been chosen, the problem is to find the needed volume of core, and to select gate, feedback and control windings that satisfy one of three objectives: minimum weight, overall dimensions, or cost.

Several chapters of the book explain analytical derivations of core volume for various types of magamp circuits. Two methods are used: 1) "linearization", which assumes that a magnetic amplifier behaves like a linear inductance and 2) "idealization", which

considers magnetic cores and rectifiers as theoretically perfect. The first method leads to relatively simple equations and makes possible the determination of core sizes and all other parameters of push-pull magnetic amplifiers with dc or ac loads. The second method, accurate only for square-loop core materials, gives good working formulas for the complete design of magnetic amplifiers of various types, including self-saturating and high speed units with resistive loads. Appropriate formulas are given for nonlinear inductive, and complex loads and for toroidal and E-I cores. The authors claim that with the analytical approach described, the difference between predicted and actual performance characteristics is only plus or minus 10 percent.

In addition to many practical problems and solutions, the book includes material on time-constants of multistage magamps with electric or magnetic feedback, the analysis of high-speed push-pull circuits, characteristics of magnetic materials, methods of measurement, and technology of high-permeability cores.

Michel Mamon
I. T. T. Laboratories, Inc.

Circuit Guide

HANDBOOK OF PREFERRED CIRCUITS, *Navy Aeronautical Electronic Equipment, NAVAER 16-1-519, Supplement No. 1.* 106 pp. *Published by Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.* $0.60.

This first supplement to *Preferred Circuits* includes five instrument servo circuits, two regulators, two high voltage supplies, a pulse a.f.c. and a silicon transistor video amplifier. Schematics of each circuit are provided, together with characteristics permitting ready selection and construction; successive pages explain use and design methods. These preferred circuits were derived after experimental measurements had been made on a large number of examples taken from both commercial and military electronic equipment. The original one-volume looseleaf Handbook, NAVAER 16-1-519 (price $1.75) was made available by the National Bureau of Standards and the Navy Bureau of Aeronautics in 1956.

MEETINGS

SEPTEMBER

American Institute of Electrical Engineers, Eighth Annual Industrial Electronics Symposium, Mellon Institute, Pittsburgh, Pa. Sept. 30-Oct. 1

OCTOBER

Institute of Radio Engineers, Fifth National Communications Symposium, Hotel Utica, Utica, N. Y. Oct. 5-7

Conference on Radio Interference Reduction, sponsored by IRE, Signal Corps, and Armour Research Foundation, Museum of Science and Industry, Chicago, Ill. Oct. 6-8

National Electronics Conference, sponsored by AIEE, IRE, Illinois Inst. of Tech., Northwestern Univ., and Univ. of Illinois, Sherman Hotel, Chicago, Ill. Oct. 12-14

American Institute of Electrical Engineers, 11th Annual Machine Tool Conference, Sheraton-Cleveland Hotel, Cleveland, Ohio Oct. 19-21

American Standards Association, Tenth National Conference on Standards, Sheraton-Cadillac Hotel, Detroit, Mich. Oct. 20-22

Fifteenth National Conference on Industrial Hydraulics, sponsored by Illinois Institute of Technology and Armour Research Foundation, Hotel Sherman, Chicago, Ill. Oct. 22-23

Institute of Radio Engineers, East Coast Aeronautical and Navigational Electronics Conference, Baltimore, Md. Oct. 26-28

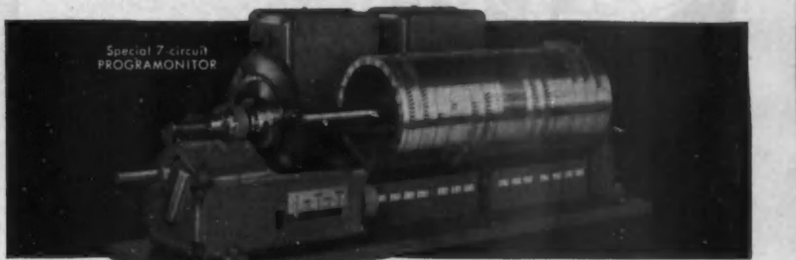
Society of Photographic Scientists and Engineers, 1959 National Conference, Edgewater Beach Hotel, Chicago, Ill. Oct. 26-30

American Institute of Chemical Engineers, N. Y. Section Meeting, Annual All-Day Symposium, Topic: Prospects for Computer-Controlled Processes, Hotel New Yorker, New York City Oct. 27

Sixth Annual Computer Applications Symposium, sponsored by Armour Research Foundation, Morrison Hotel, Chicago, Ill. Oct. 28-29

Aircraft Electrical Society, Annual Industry Display, Pan Pacific Auditorium, Los Angeles, Calif. Oct. 28-30

Institute of Radio Engineers, 1959 Electron Devices Meeting, Shoreham Hotel, Washington, D. C. Oct. 29-30



MEETINGS

NOVEMBER

American Society for Metals, 41st National Exposition and Congress, International Amphitheatre, Chicago, Ill. Nov. 2-6

11th Annual Mid-America Electronics Conference, Hotel Muehlebach, Kansas City Municipal Auditorium, Kansas City, Mo. Nov. 3-5

American Nuclear Society, Winter Meeting, Sheraton Park Hotel, Washington, D. C. Nov. 4-6

Institute of Radio Engineers, National Conference on Automatic Control, New Sheraton Hotel, Dallas, Tex. Nov. 4-6

Institute of Radio Engineers, Fourth Instrumentation Conference, Atlanta Biltmore Hotel, Atlanta, Ga. Nov. 9-11

National Electrical Manufacturers Association, Annual Meeting, Atlantic City, N. J. Nov. 9-12

Conference on Magnetism and Magnetic Materials, sponsored by IRE and AIEE, Sheraton-Cadillac Hotel, Detroit, Mich. Nov. 16-19

American Society of Mechanical Engineers, Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J. Nov. 29-Dec. 4

27th Exposition of Chemical Industries, New York Coliseum, New York City Nov. 30-Dec. 4

DECEMBER

Eastern Joint Computer Conference, sponsored by AIEE, ACM, and IRE, Hotel Statler, Boston, Mass. Dec. 1-3

American Institute of Chemical Engineers, Annual Meeting, Sheraton Palace Hotel, San Francisco, Calif. Dec. 6-10

JANUARY

Sixth National Symposium on Reliability and Quality Control, sponsored by IRE, AIEE, ASQC, and EIA, Statler Hilton Hotel, Washington, D. C. Jan. 11-13

American Institute of Electrical Engineers, Winter General Meeting, New York City Jan. 31-Feb. 5

FEBRUARY

Instrument Society of America, Instrument-Automation Conference and Exhibit, Houston Coliseum, Houston, Tex. Feb. 1-5

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The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

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Continued on page 216

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ples, practical tips, and the use of these techniques in automatic process control. 60 cents.

Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This reprint covers a broad selection of multivibrator circuits that are especially applicable to control systems. 45 cents.

A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. A survey of equipment and tips on using it. 60 cents.

Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Largely regarded as constant-speed devices, multi-speed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

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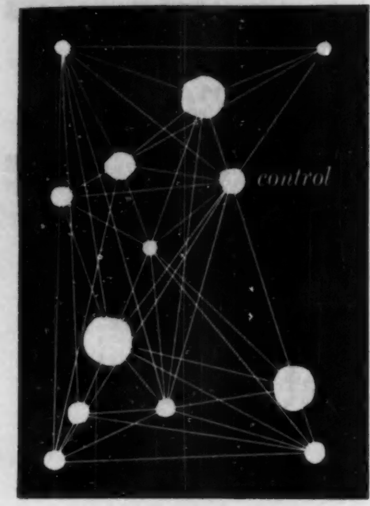

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